Target Fabrication Capabilities

Presented to
NIF Users Group
February 14, 2012

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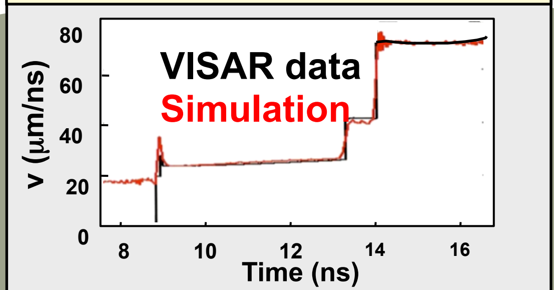
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

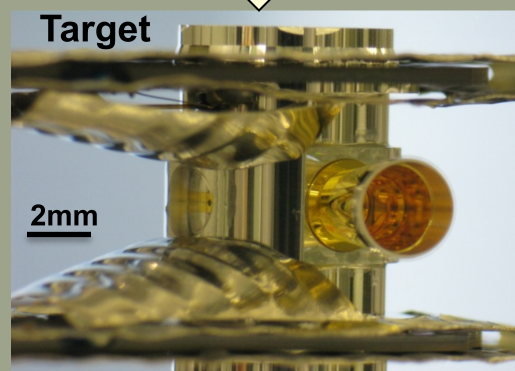
Target Fabrication team has the capabilities to build a wide variety of targets to investigate fundamental science on NIF

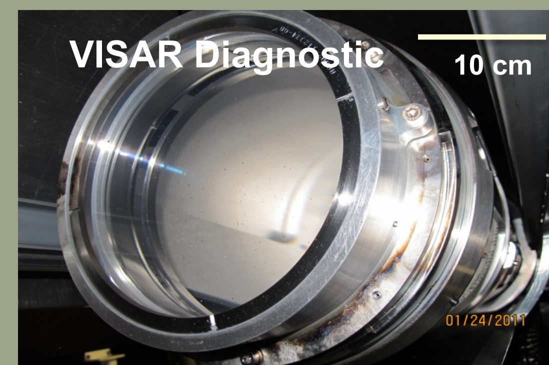
NIF

The target is one of the key elements of a successful experiment

Design

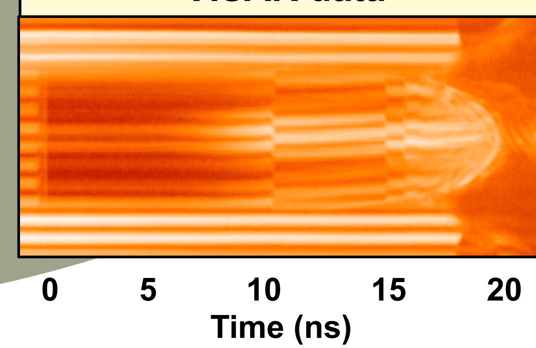




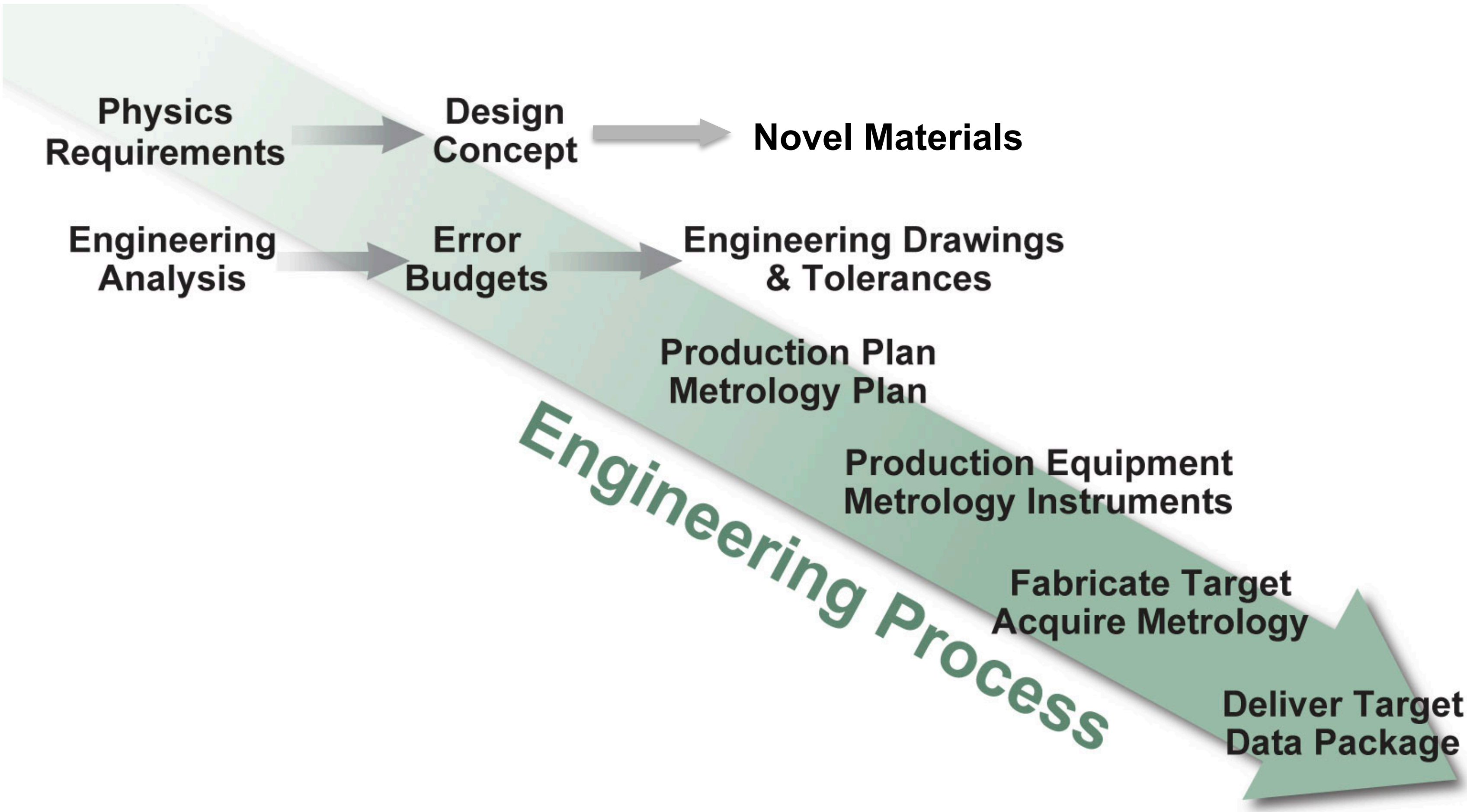


Results!!

VISAR data



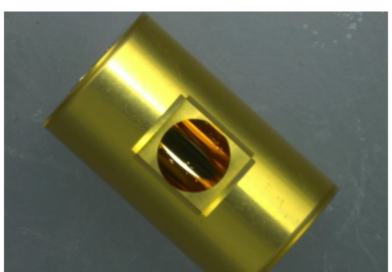
Discipline is critical to the success of the effort



We can make the impossible, but it might take a little time

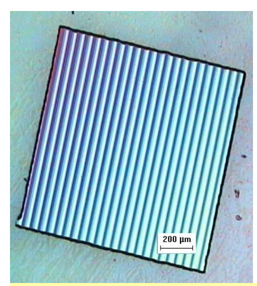
Target Components

- Hohlraums, half hohlraums (vacuum and gas filled)– Gold, Uranium, Pb
- Capsules – CH(Ge), Be(Cu), High density carbon (W), SiO_2, Au/Cu
- Stepped and rippled planar packages – Al, Cu, Foam (Aerogel and Metal), High density carbon, Ta, Fe, LiF
- Cones – Gold
- Shields



"Hohlraums"

Capsules



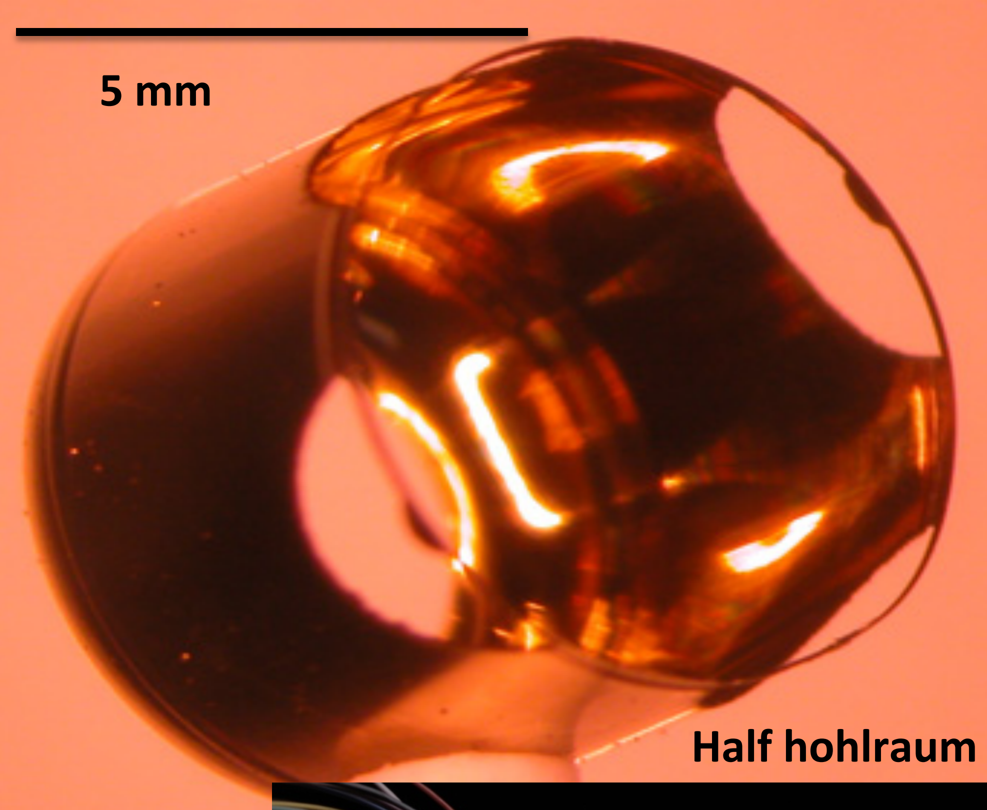
Rippled HDC

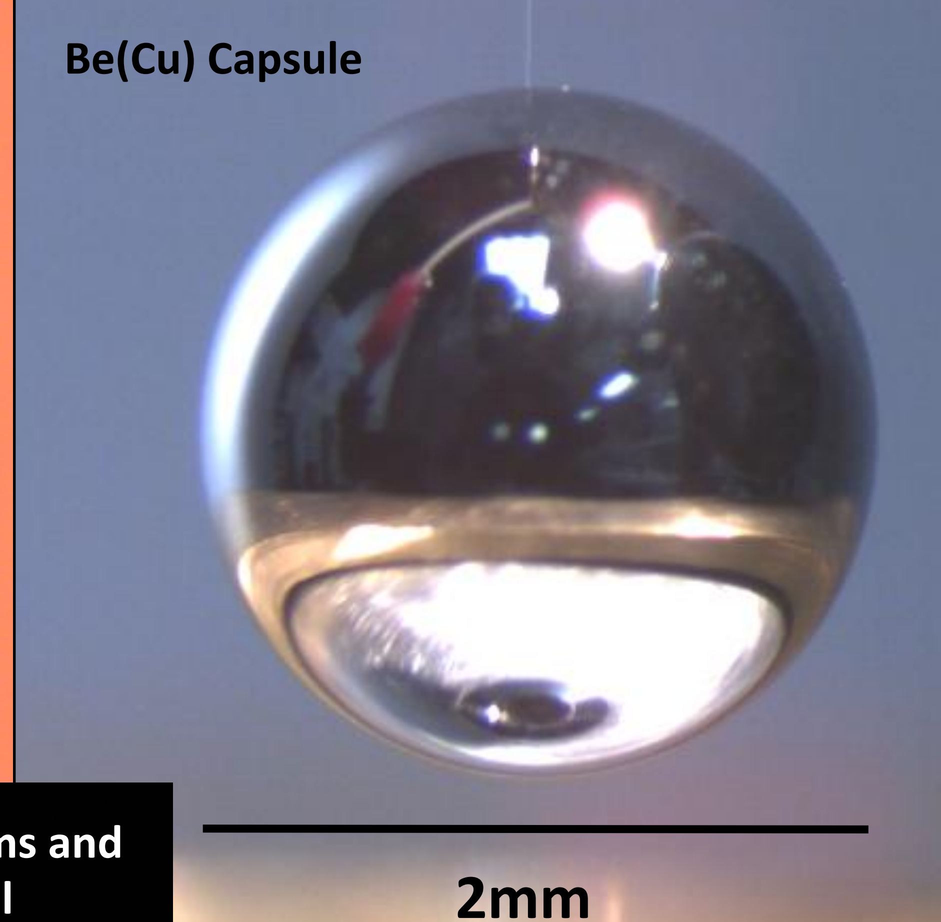
Gold Cone

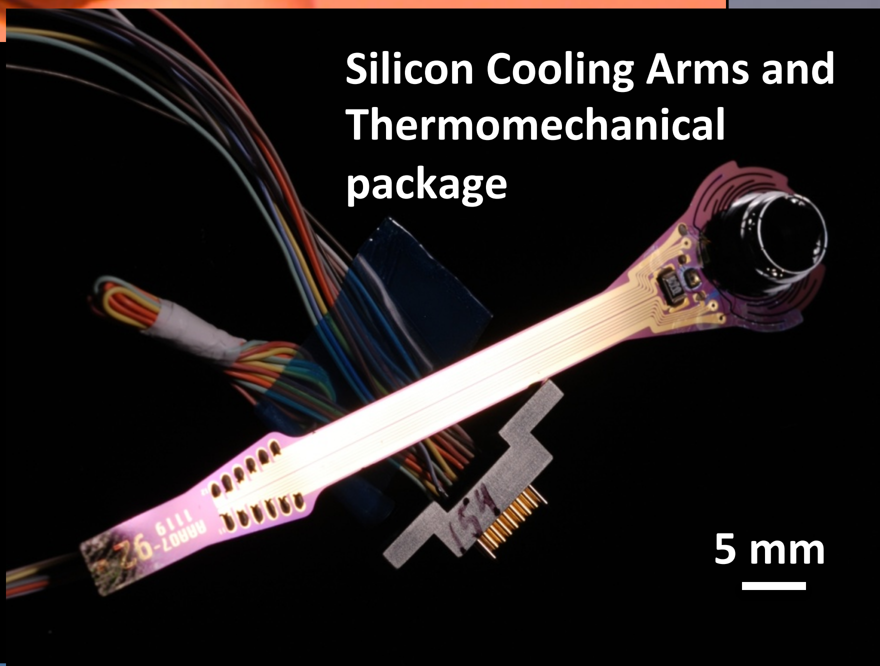
Unconverted light shield

Target Fabrication Capabilities

- Micromachining - diamond turning lathes, precision milling, precision grinding, laser machining, polishing, lithography
- Physical vapor deposition (ion assisted), chemical vapor deposition (plasma assisted), electro-deposition, atomic layer deposition
- Doping, Implantation
- Novel Materials – Aerogels, Nanoporous metals
- Precision Assembly
- Component and Target Metrology





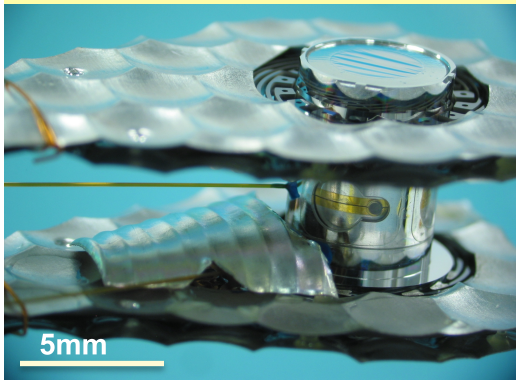


General Atomics is an integrated partner in target fabrication

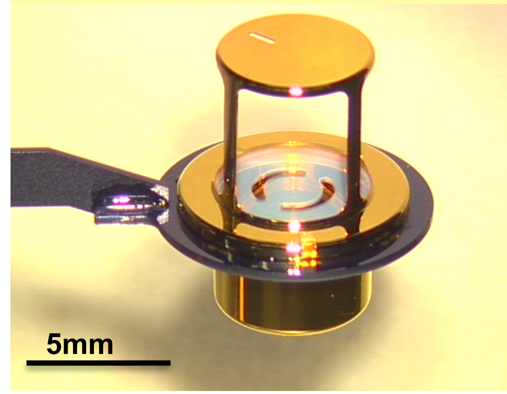
GENERAL ATOMICS

A number of target platforms have been commissioned on NIF

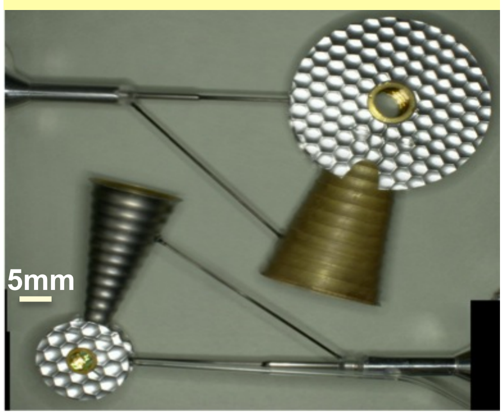
Cryogenic Ignition and Tuning



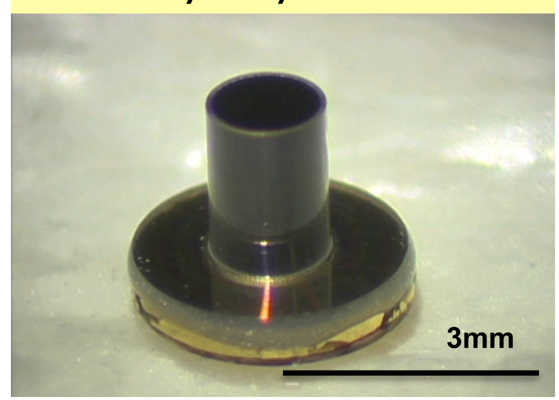
Radiation Transport



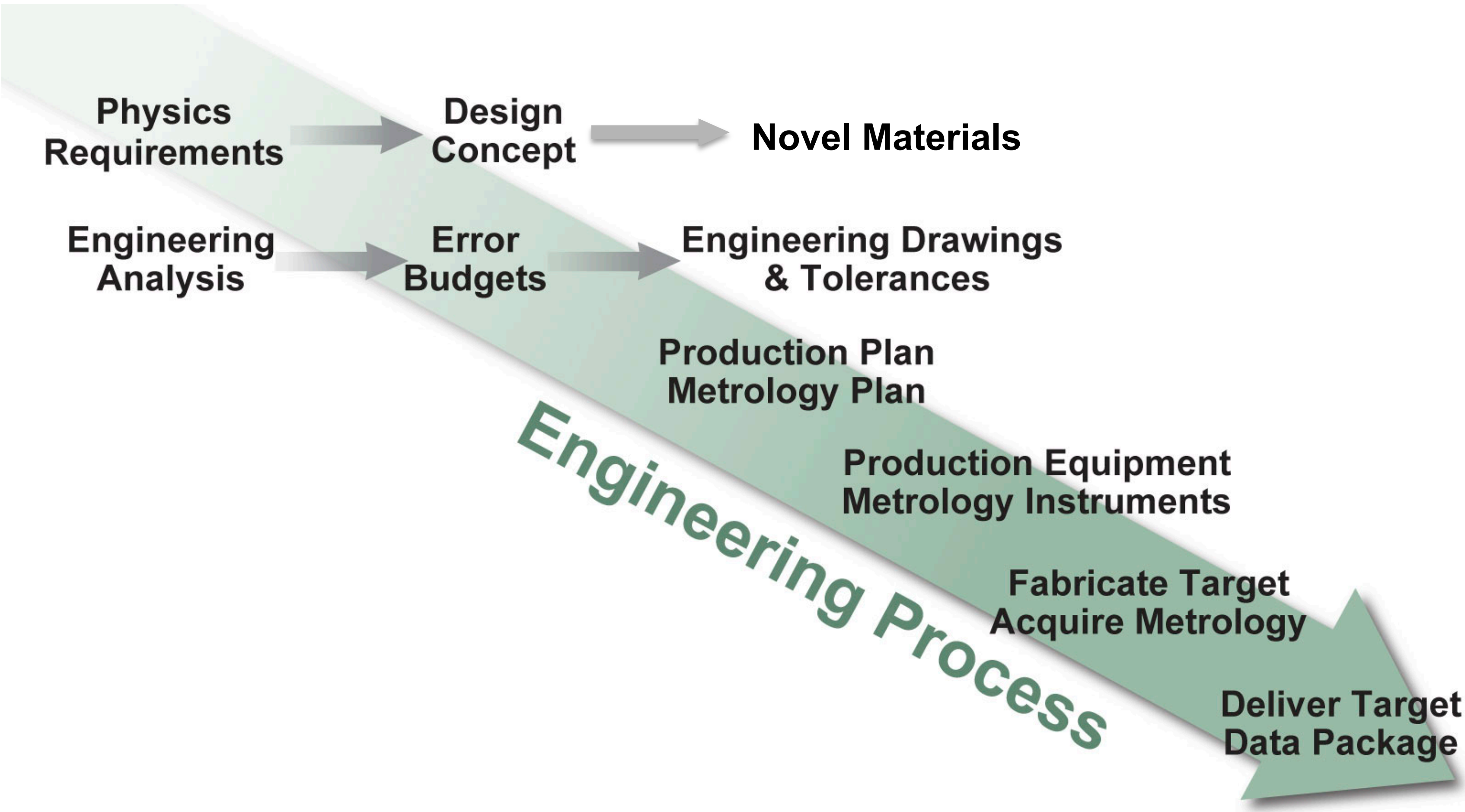
Materials Dynamics and Equation of State



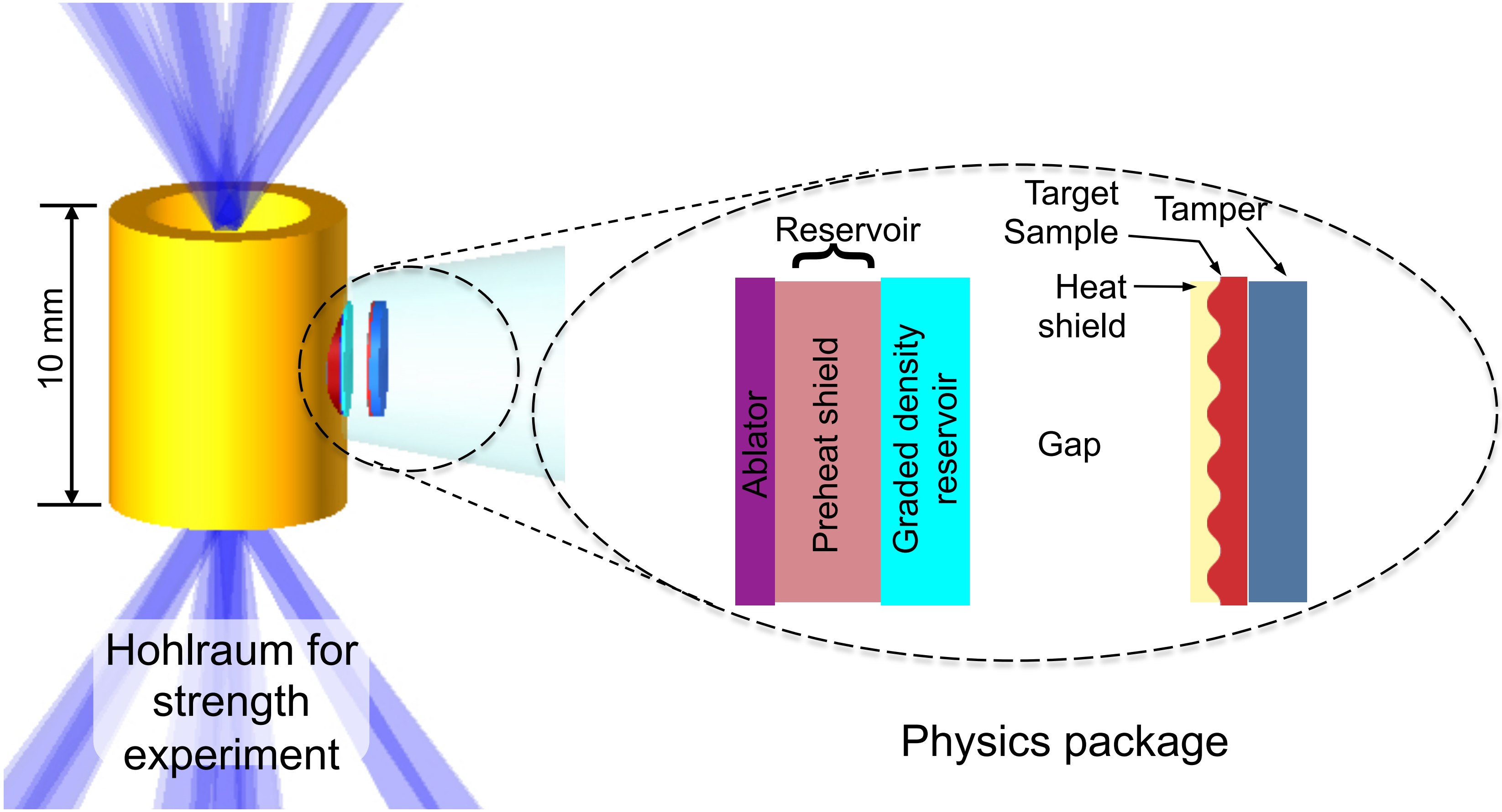
Hydrodynamics



Discipline is critical to the success of the effort

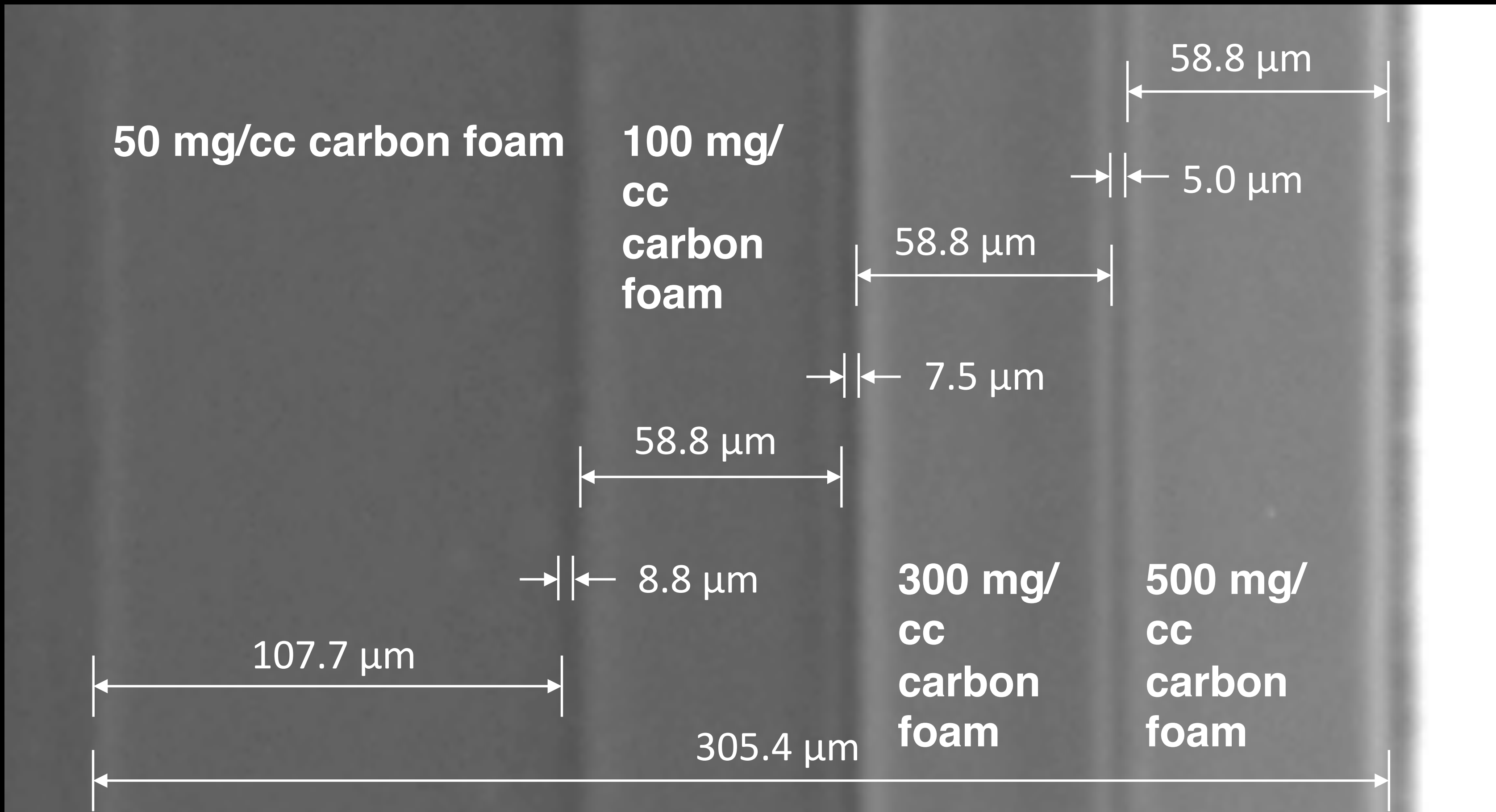


Materials dynamics experiments will measure the resistance-to-deformation of samples at high pressure



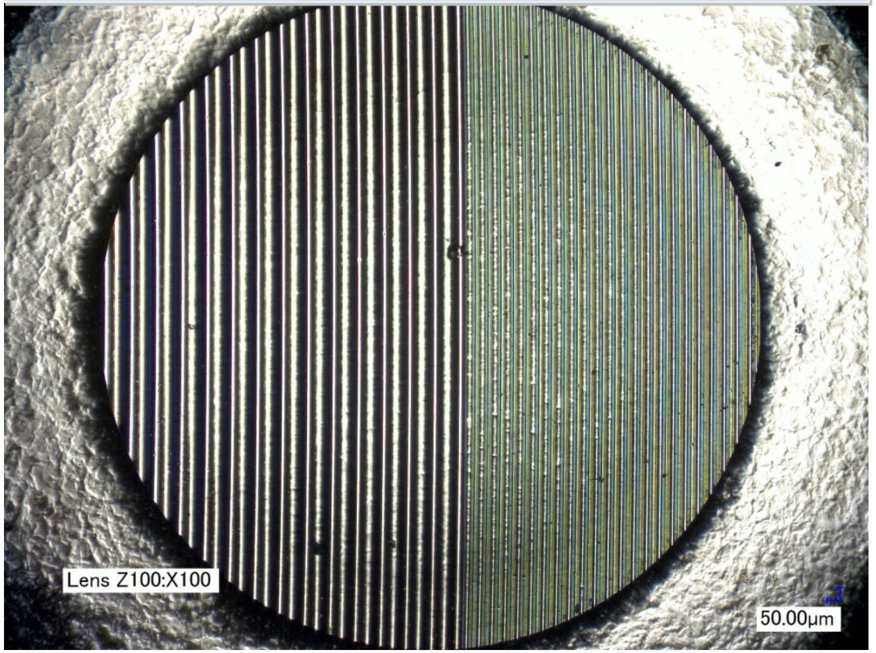
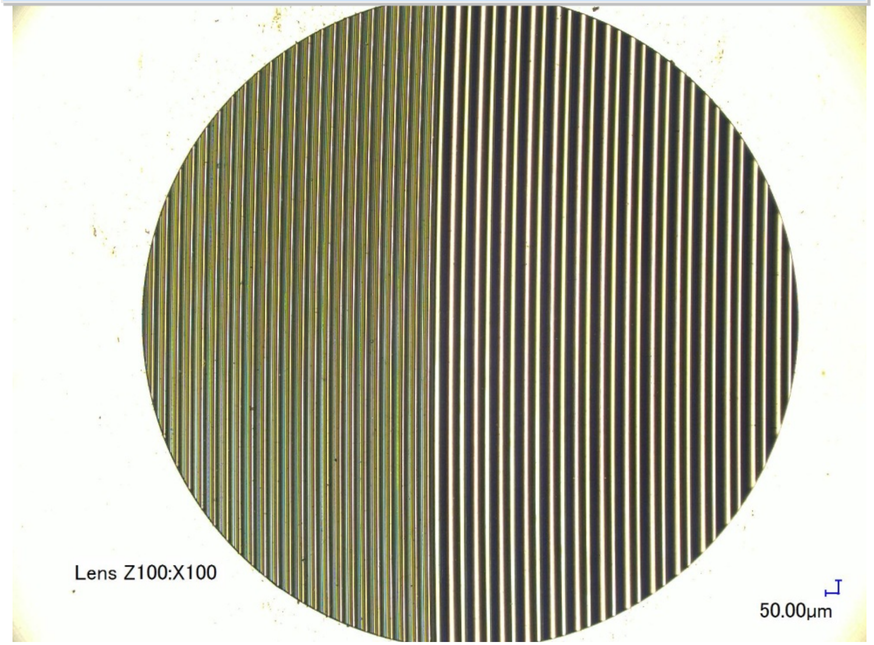
- **Critical target fabrication challenges include:**
  - **— Low Z graded density structures from 1 to 0.001 g/cc**
  - **— Rippled Ta and V samples with small grain size and appropriate thickness**

Silica aerogel “glue” was invented to produce step graded density reservoir



“Negative” digital radiograph of stepped graded density reser voir

Rippled Ta samples were produced by coining so that resistance-to-deformation of wrought materials can be measured

Rippled Ta produced by coining	Coining die
	

50 and 100 micron period 4 micron peak to valley ripples were successfully transferred to the Ta sample

White light interferometry provides target metrology

Surface Stats:

Ra: 1.22 um

Rq: 1.36 um

Rt: 4.56 um

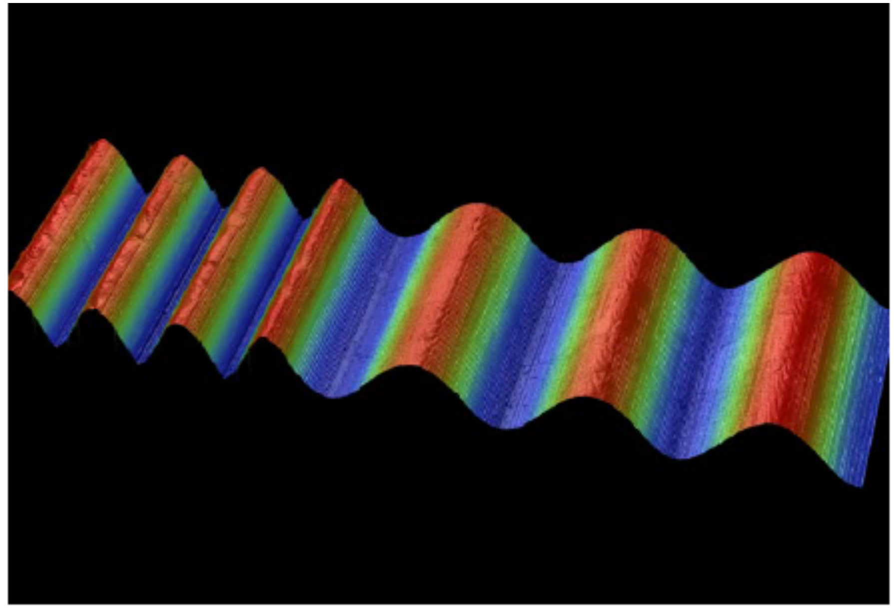
Measurement Info:

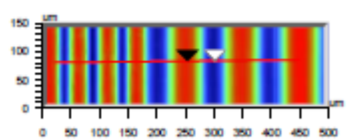
Magnification: 50.22

Measurement Mode: VSI

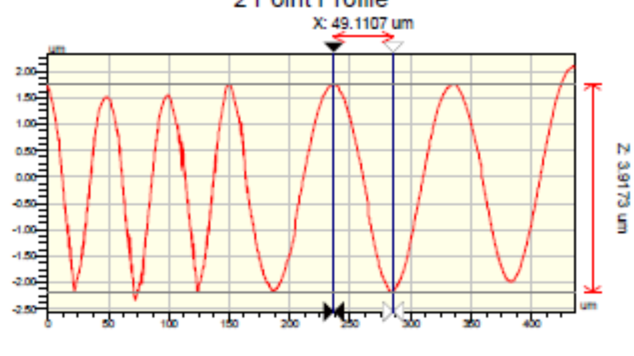
Sampling: 197.13 nm

Array Size: 2536 X 761





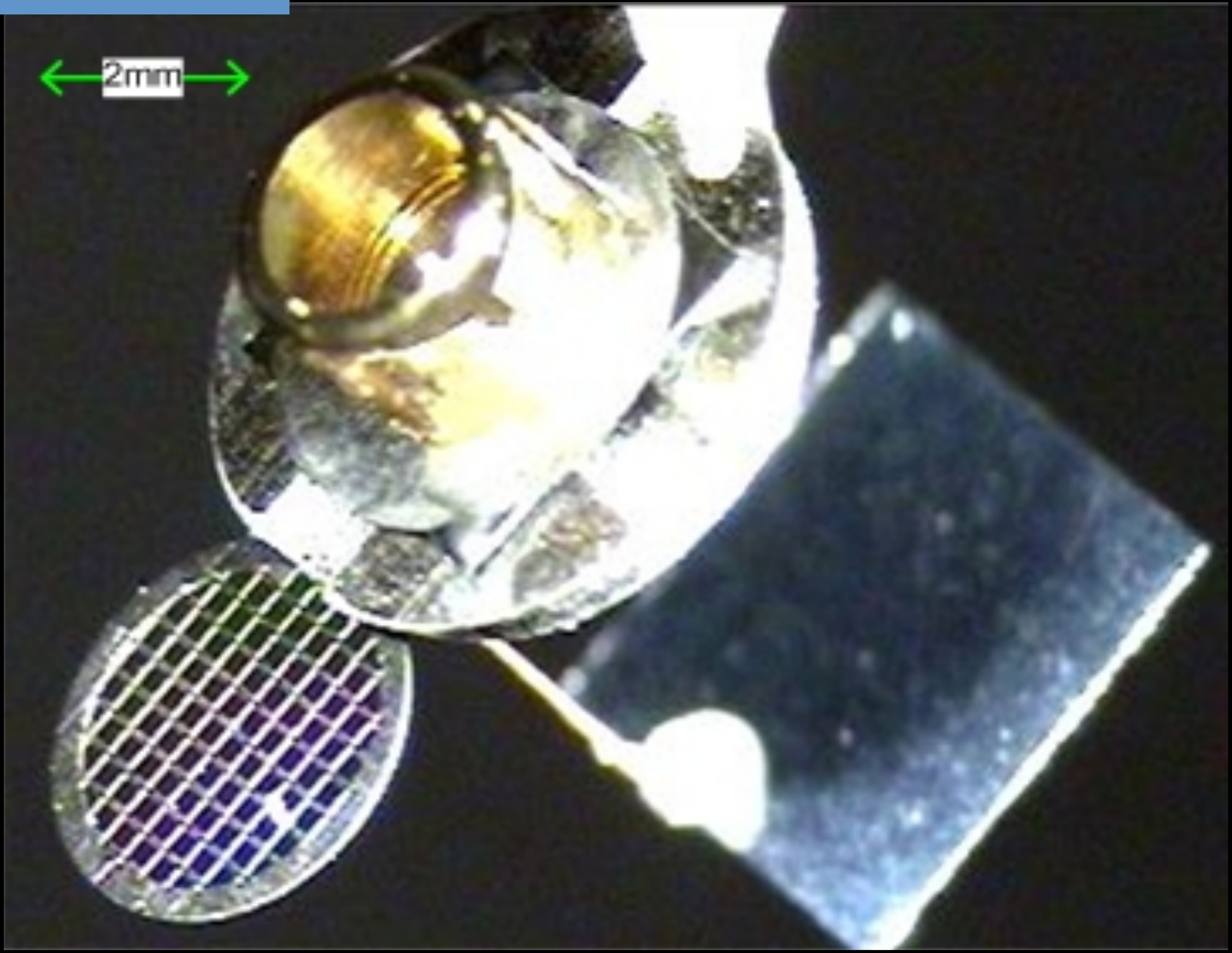
2 Point Profile



Rq	1.40	um
Ra	1.26	um
Rt	3.93	um
Rp	1.75	um
Rv	-2.18	um

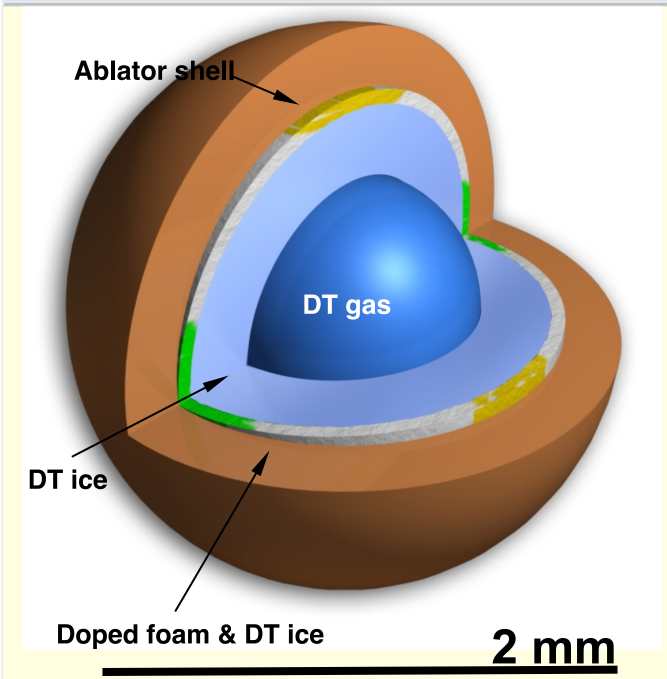
Angle	-79.63	mrad
Curve	-2.09	mm
Terms	None	
Avg Ht	-0.17	um
Area	-8.44	um2

Materials Dynamics



Nuclear physics experiments may require placing isotopes in or near a burning plasma

Fusion Applications Target

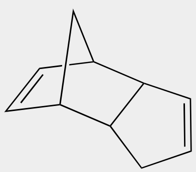


- A non-shrinking low-density nanoporous scaffold is being designed
- Casting of the precursor is being studied
- Whether the scaffold can survive hydrogen wetting is also under investigation
- Doping of the scaffold is also being explored

New aerogels are being designed for nuclear physics experiments as a scaffold for dopants

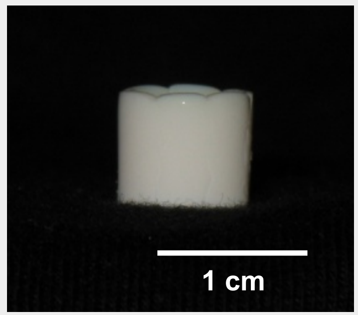
Non-shrinking low-density polymer aerogels

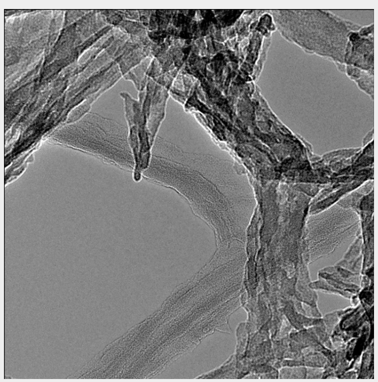
Dicyclopentadiene (DCPD) cross-linked polymer network



DCPD monomer

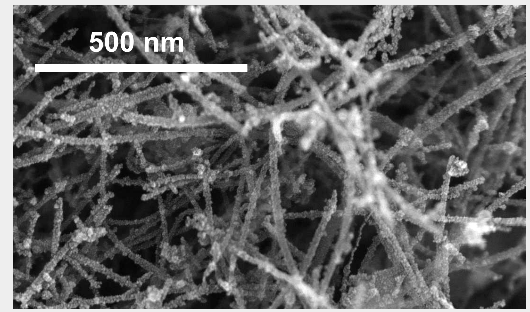
Ru catalyst → toluene



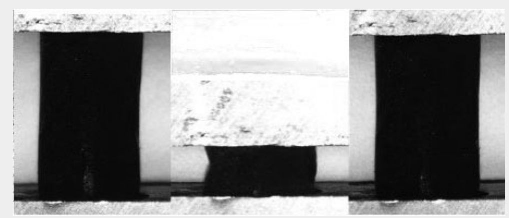


TEM Image of a 30 mg/cc DCPD aerogel

Carbon nanotube reinforced carbon aerogels



Requires high temperature pyrolysis, but elastic behavior up to very large (~90%) strains

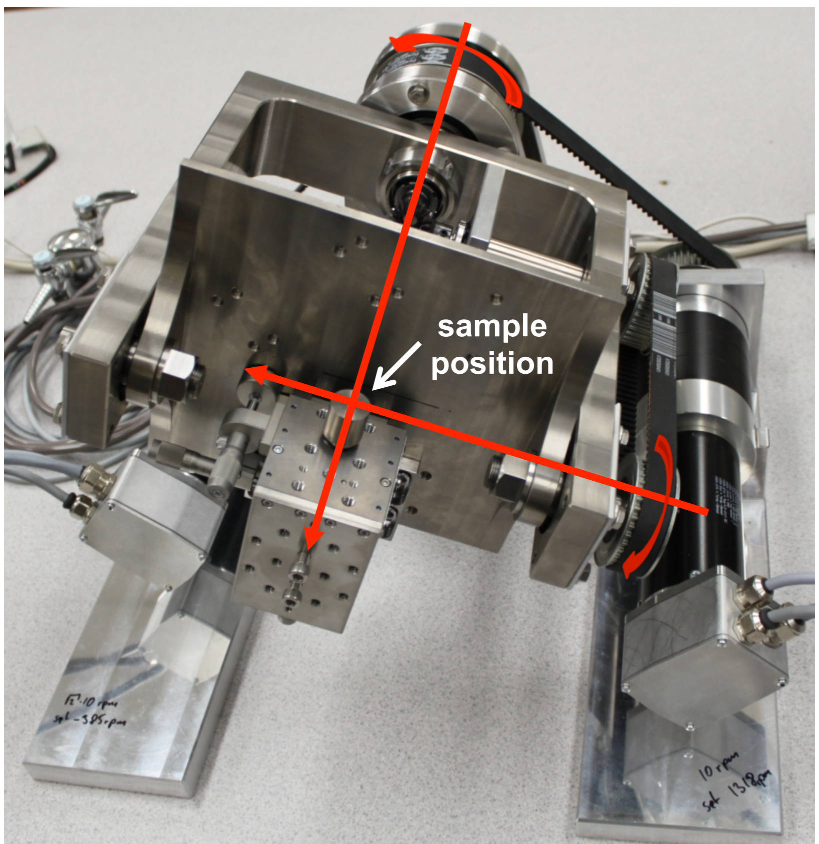


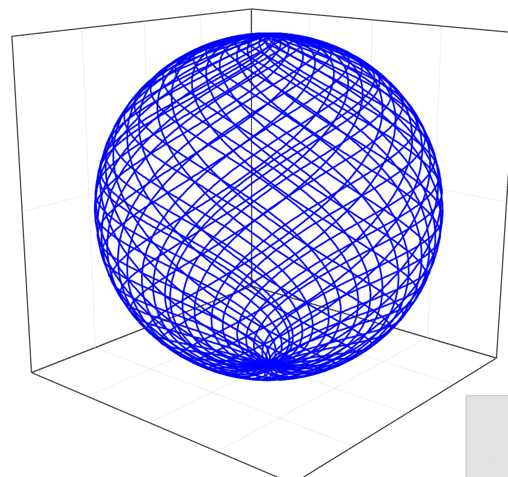
Worsley M.A. *et al.* 2009 *Appl. Phys. Lett.* 94, 073115
Worsley M.A. *et al.* 2009 *J. Mater. Chem.* 19, 3370
Worsley M.A. *et al.* 2008 *Langmuir* 24, 9763

We have developed mechanical robust, ultra-low density polymer and carbon aerogels

Deterministic Layer Formation

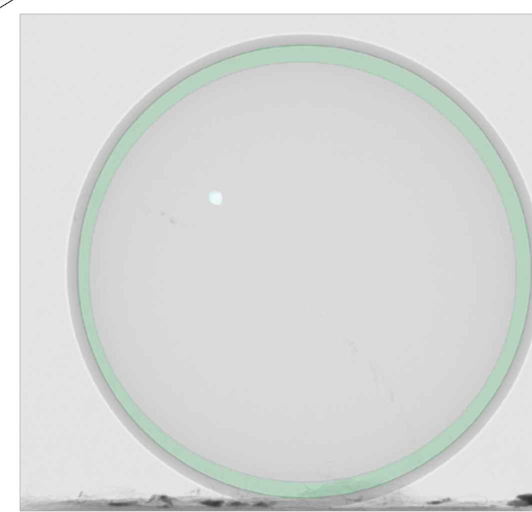
Two perpendicular and independently driven rotating frames provide a deterministic, continuous change in orientation relative to the gravity simulating a microgravity environment.



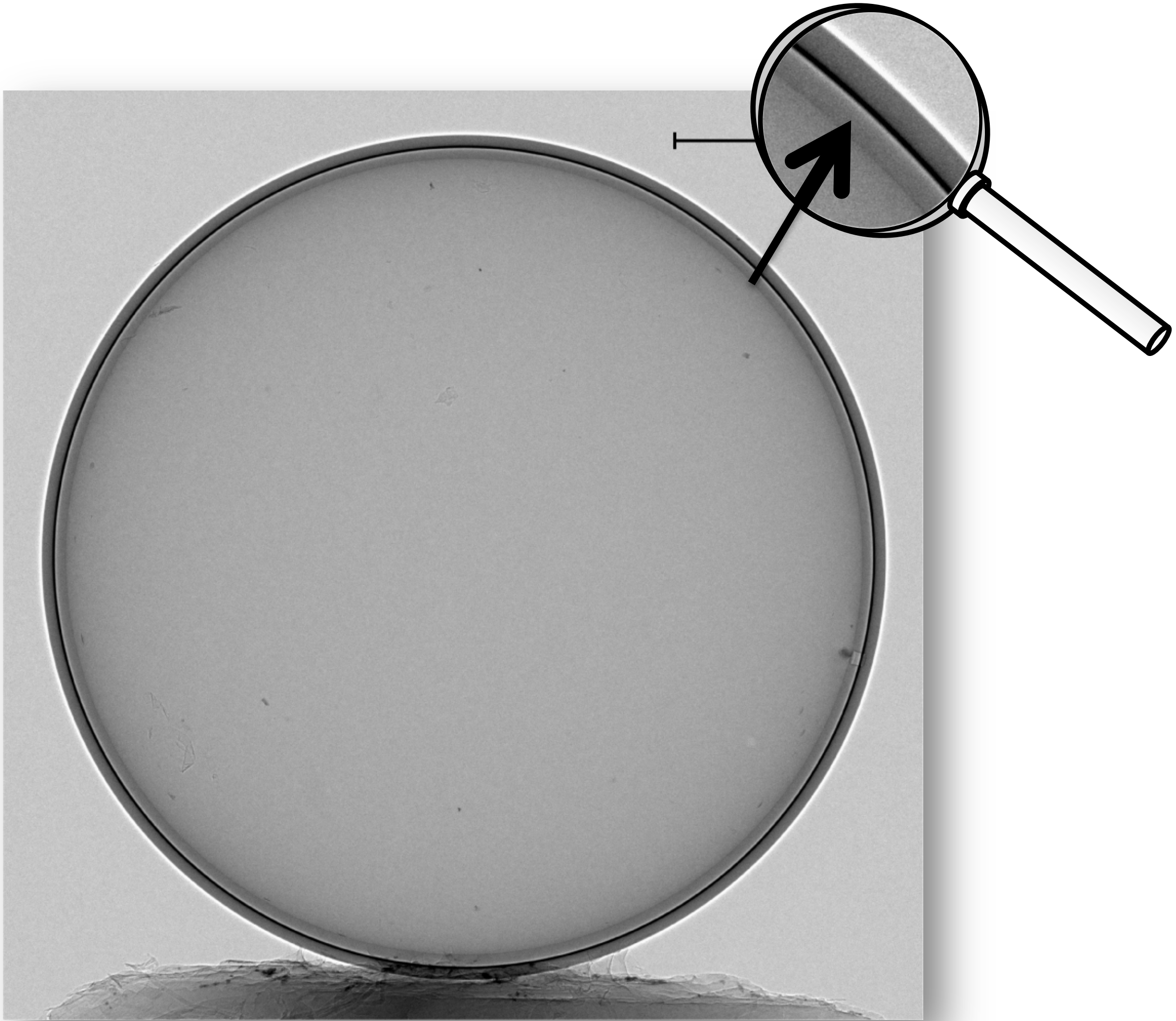


Projected track of a point on a sphere after 150 sec (10 and 14.14rpm)

2 mm diamond shell with an ~50-micron-thick layer of a DCPD polymer gel



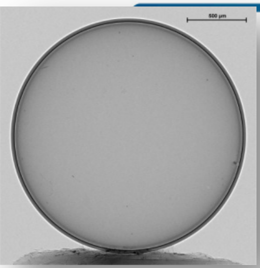
Uniform and smooth foam coatings can be fabricated



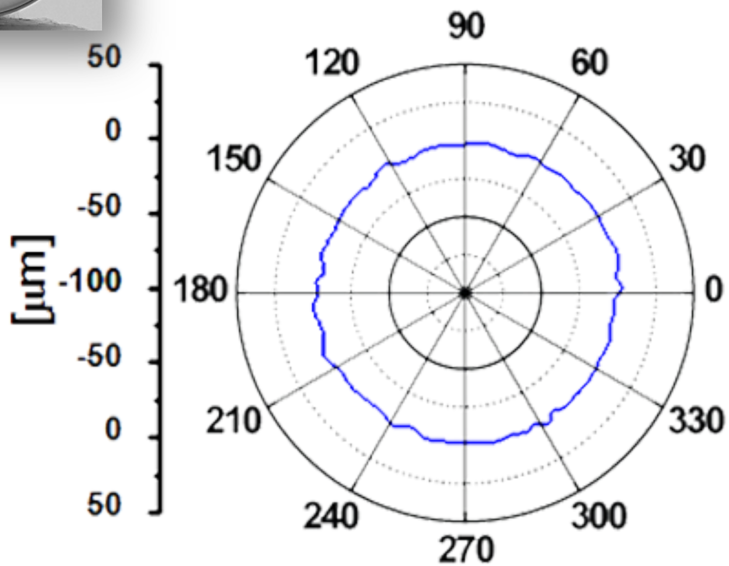
Capsule coated with a ~40 μm thick uniform DCPD/NB foam layer

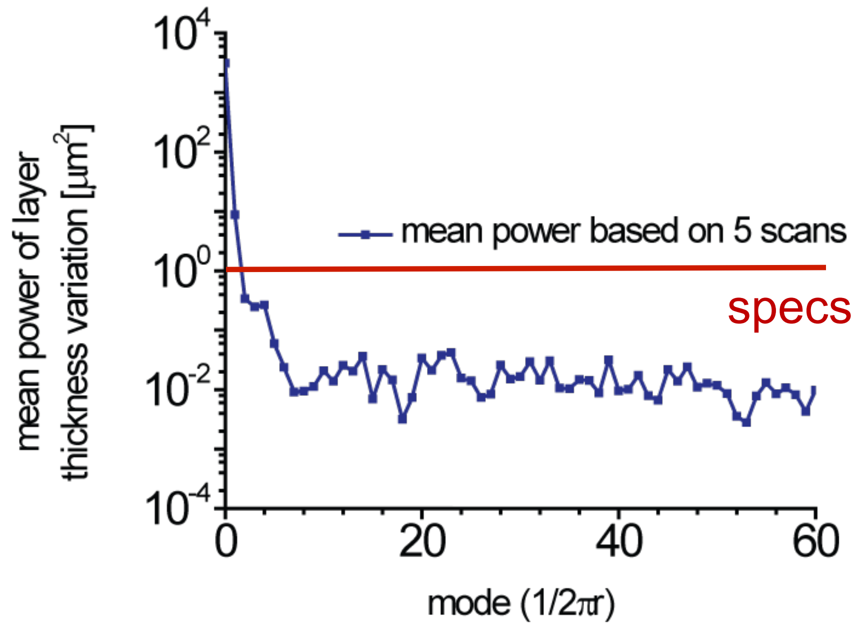
(50 mg/cc DCPD with 10% Norbornene, iodine doped and super-critically dried)

Uniform and smooth foam coatings can be fabricated



Concentricity and inner surface roughness of dried foam shell

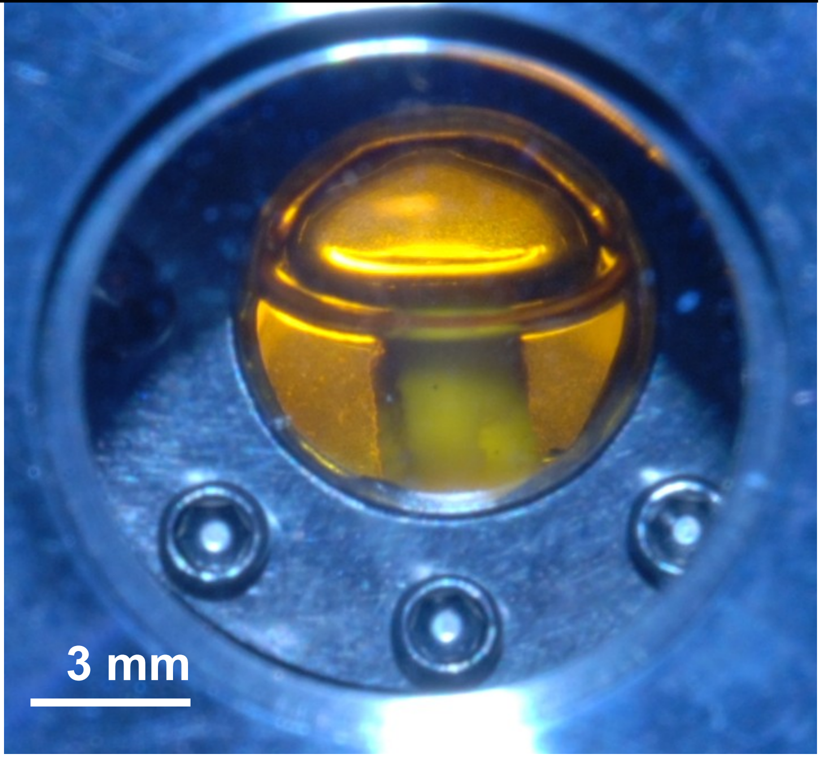




The non-concentricity (mode 1) is less than 3 micron, and the high mode surface roughness (> mode 10) is less than 10 nm.

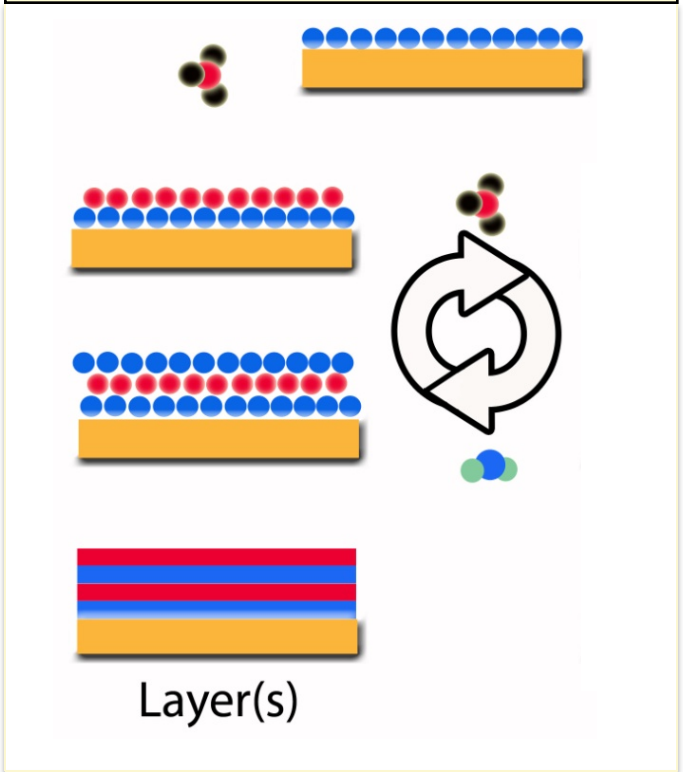
The scaffold has to withstand the capillary pressure of hydrogen wetting

Organic aerogel immersed in liquid hydrogen



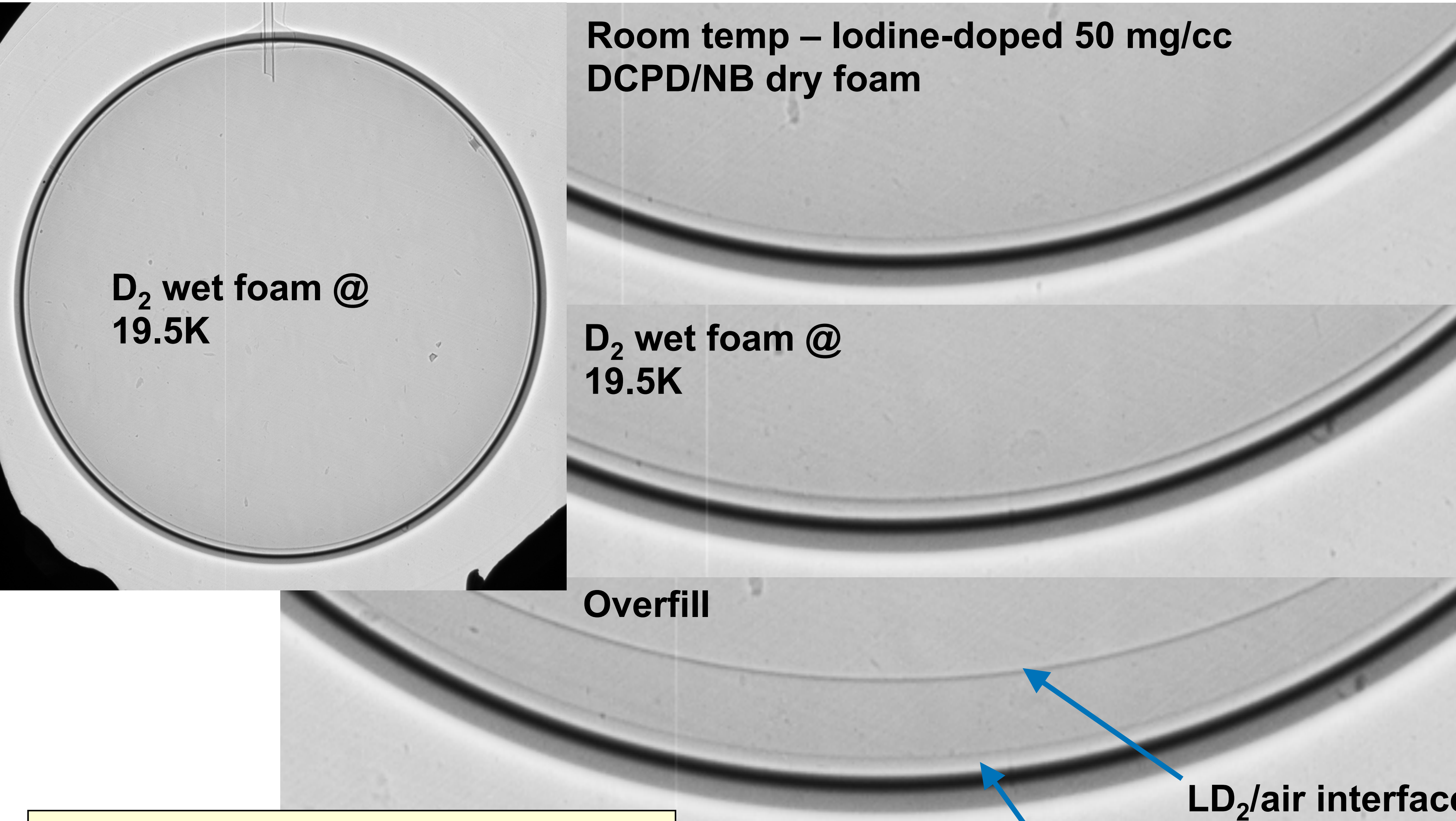
Atomic layer deposition is being used for doping of the Nanoporous materials

Atomic layer deposition process



Ruthenium Doped Carbon Aerogel

D_2-fill experiments

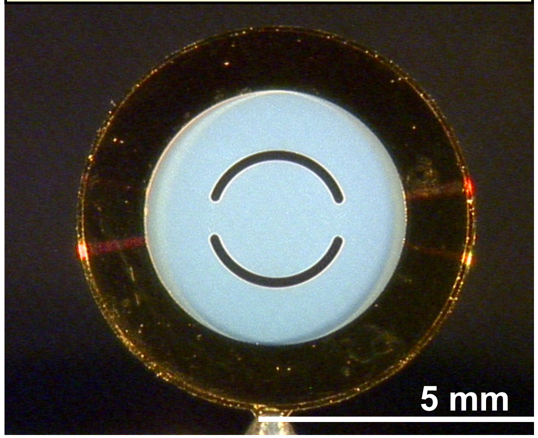


Aerogel layer defines liquid D_2 layer

Novel materials are frequently needed

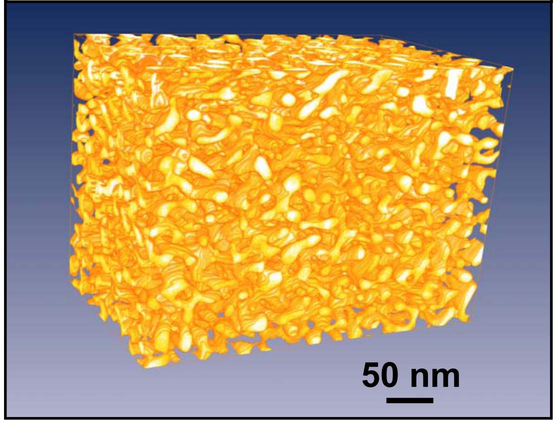
Metal Oxide Aerogels

Single Slot Target

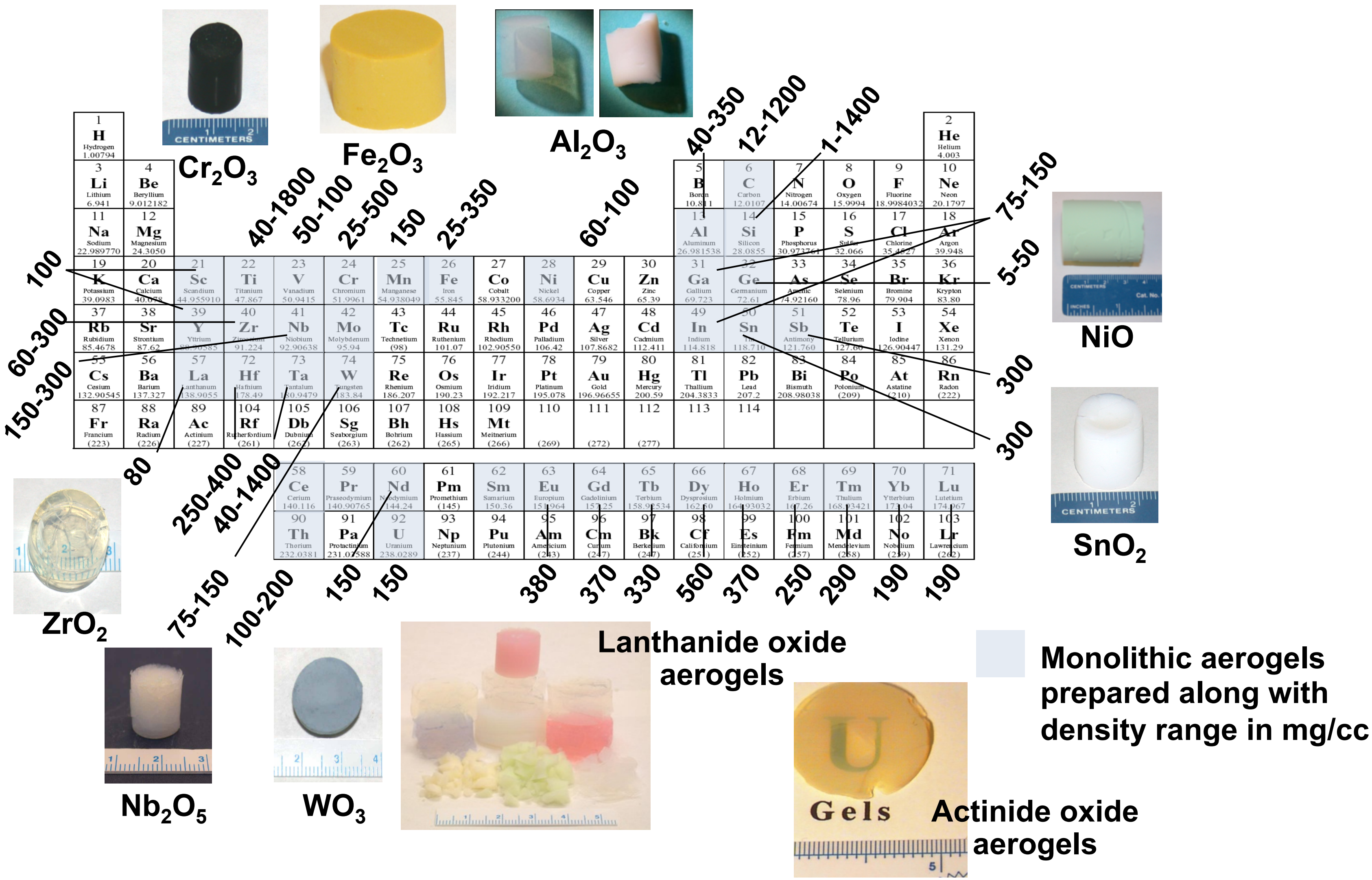


Nanoporous Metals & Organic Aerogels

High-Z Nanoporous Metals



A broad range of monolithic aerogel compositions have been synthesized

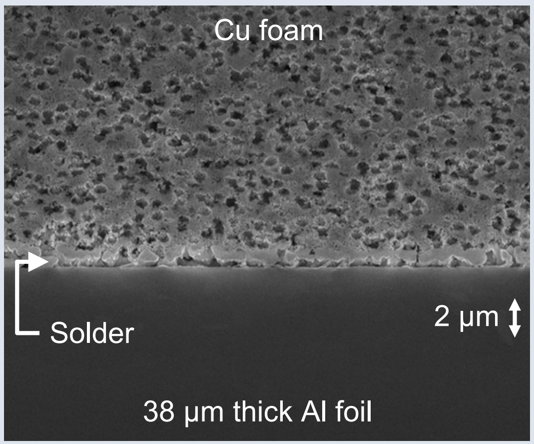


New materials, novel engineering and advanced fabrication techniques are often required

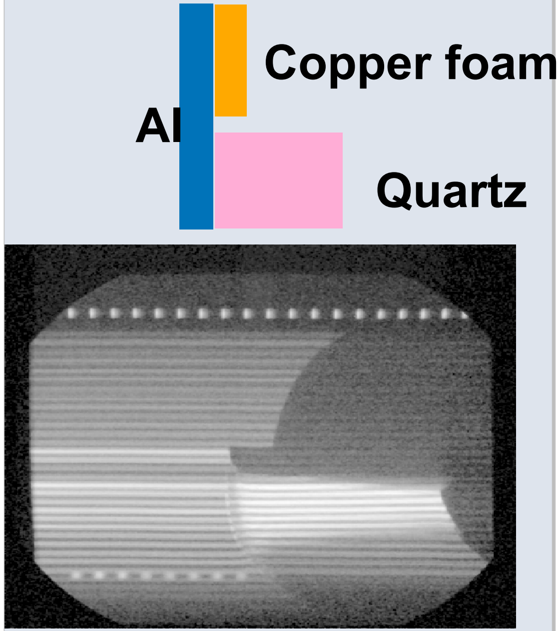
Copper Foam (cast, machined, and cut)

8-15% relative density

SEM of Copper foam/Al bond line



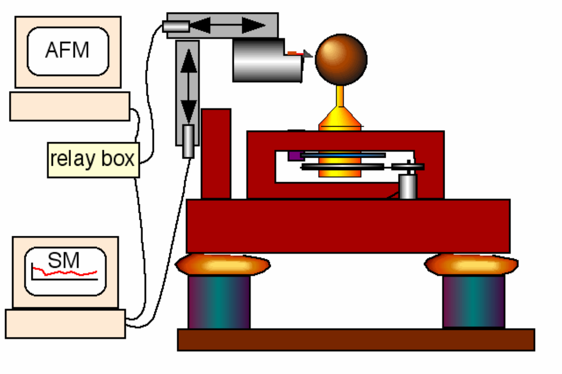
VISAR signal showing shock breakout

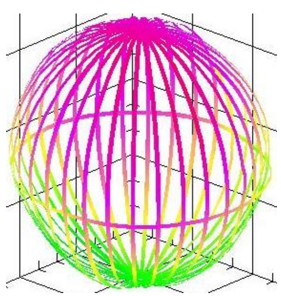


Various metrology tools are used to determine target specifications are met (i.e. capsule shape, isolated defects and homogeneity)

Atomic Force Spheremapper	Phase Shifting Diffractive Interferometry (PSDI)	Precision Radiograph

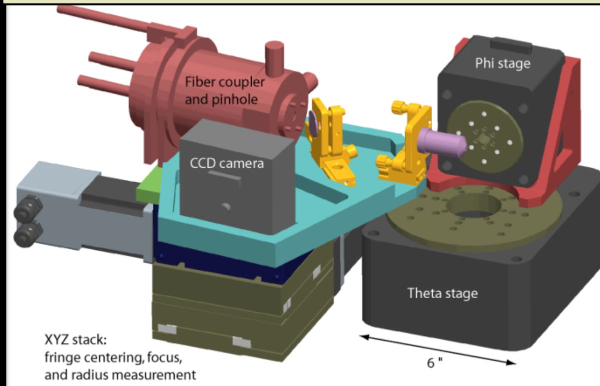
Atomic Force Spheremapper

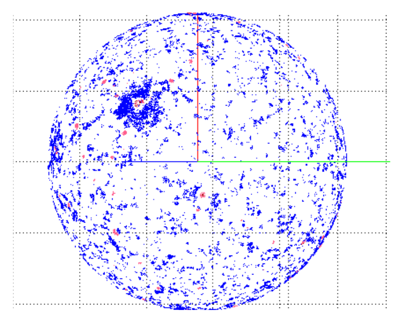




Shape and roughness

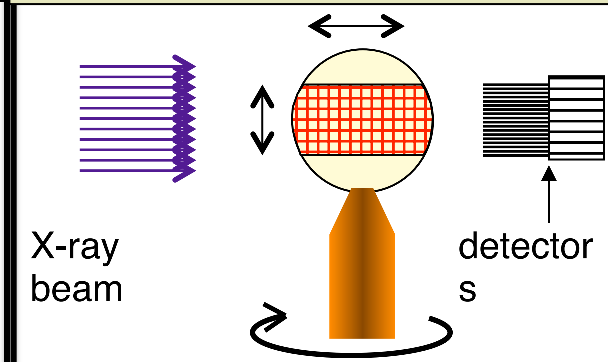
Phase Shifting Diffractive Interferometry (PSDI)

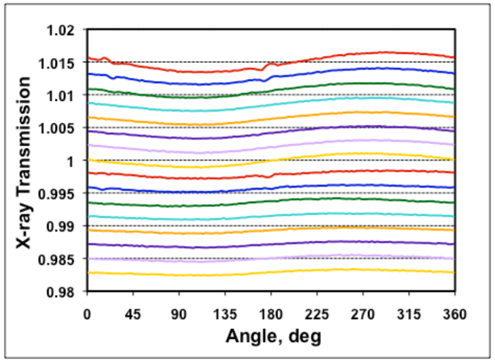




Isolated defects & uniformity

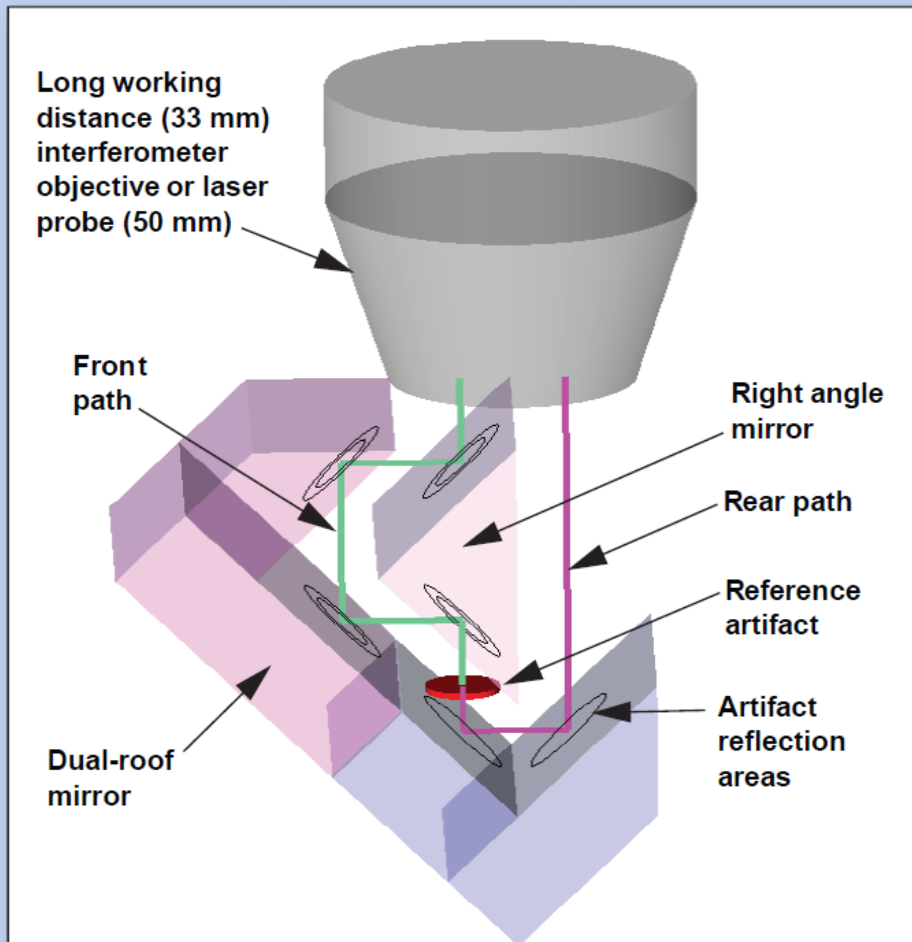
Precision Radiograph

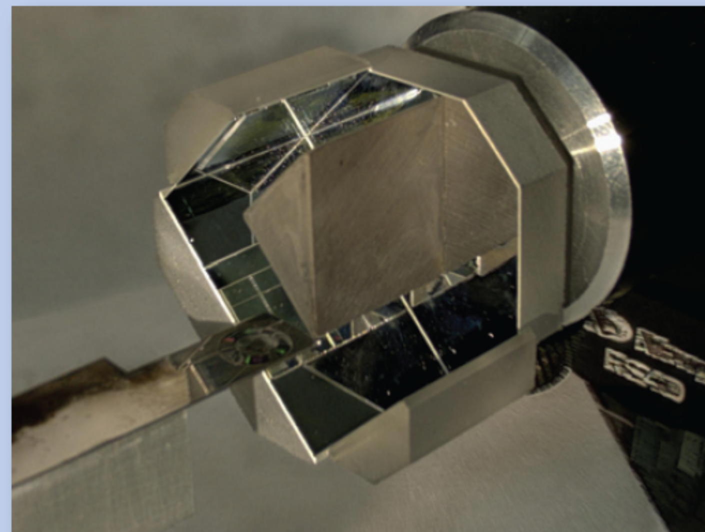




Uniformity

Double-sided White-light interferometer is used to scan both sides of a sample simultaneously

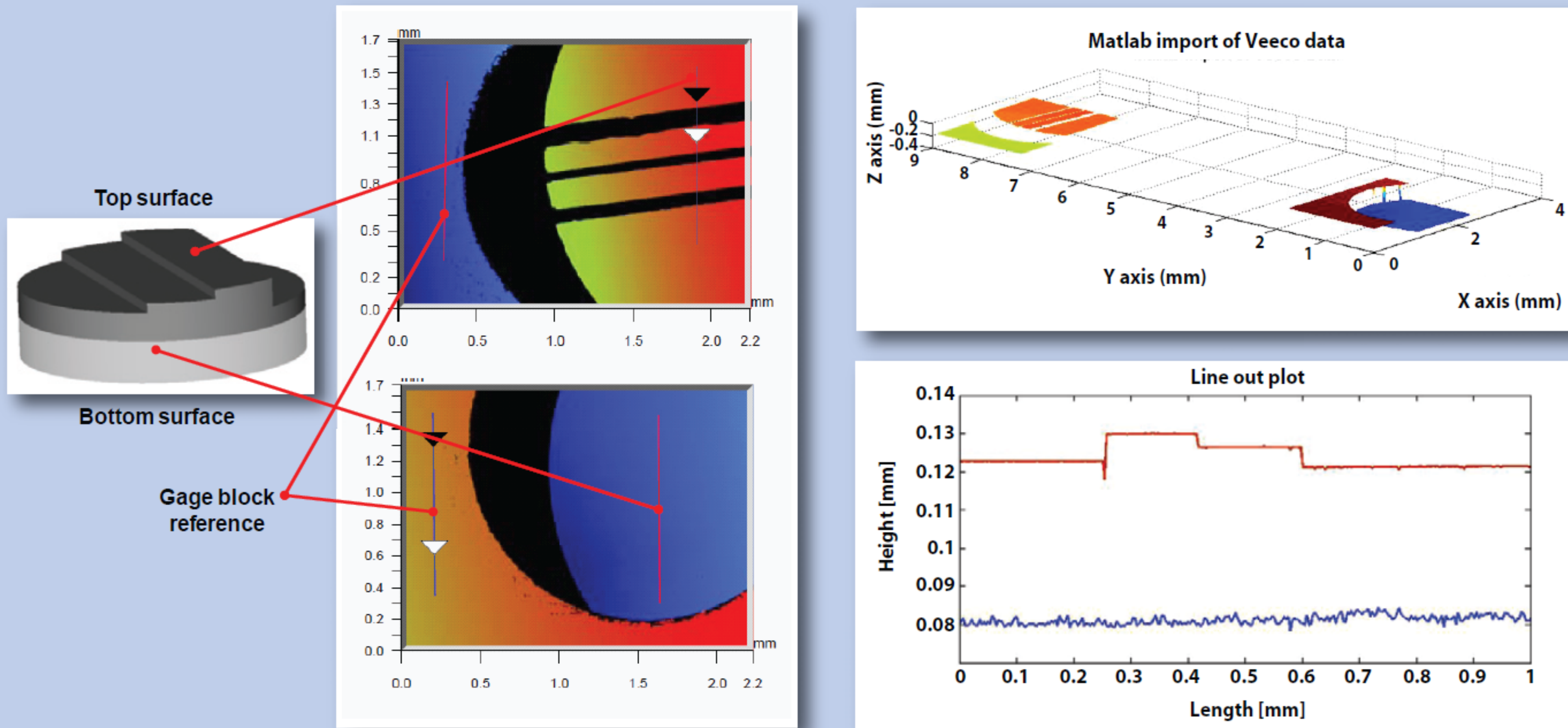




The above image represents the dual-roof mirror/right angle mirror design, measuring system objective and reference artifact. Equal length front and rear paths are schematically shown

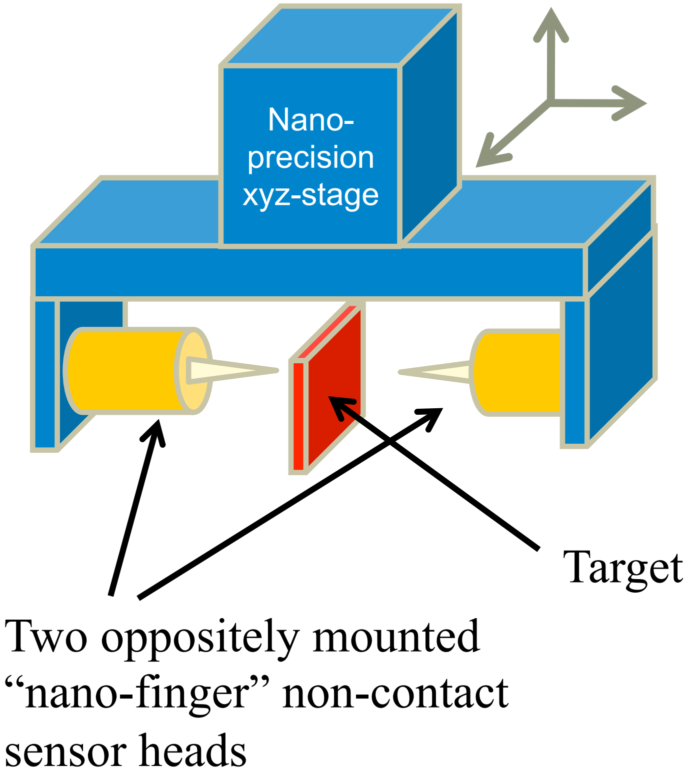
Measurement of a stepped diamond sample front and rear surfaces using double side interferometer

Stepped Diamond Measurement

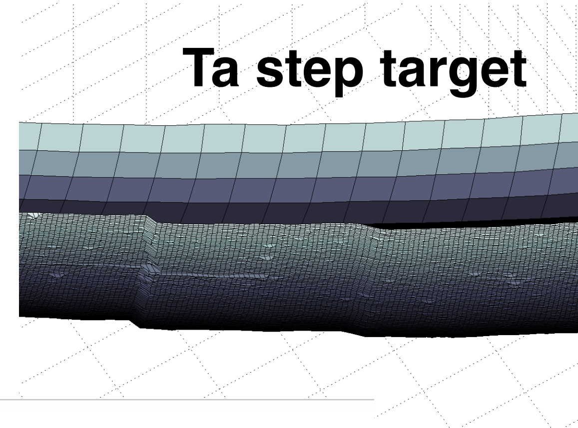


3D mapping of ripple and step targets to ~ 1 micron accuracy

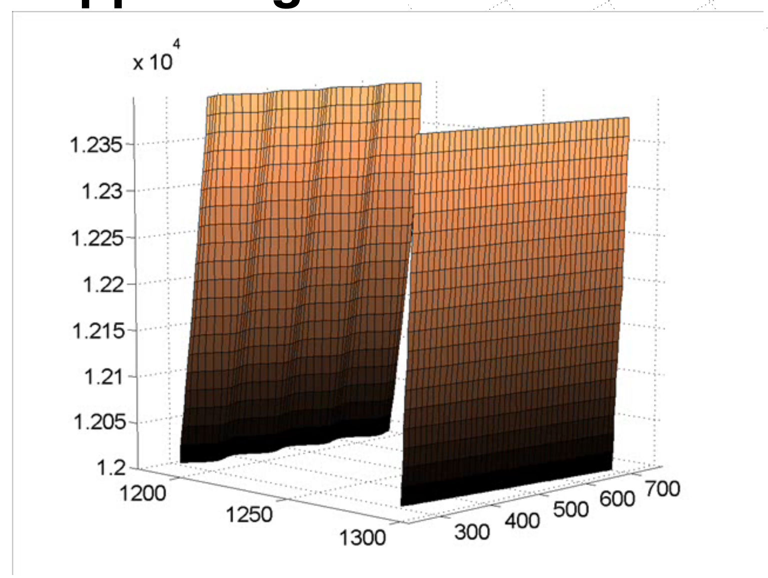
3D mapping of millimeter-sized structures with nanometer precision



Ta step target



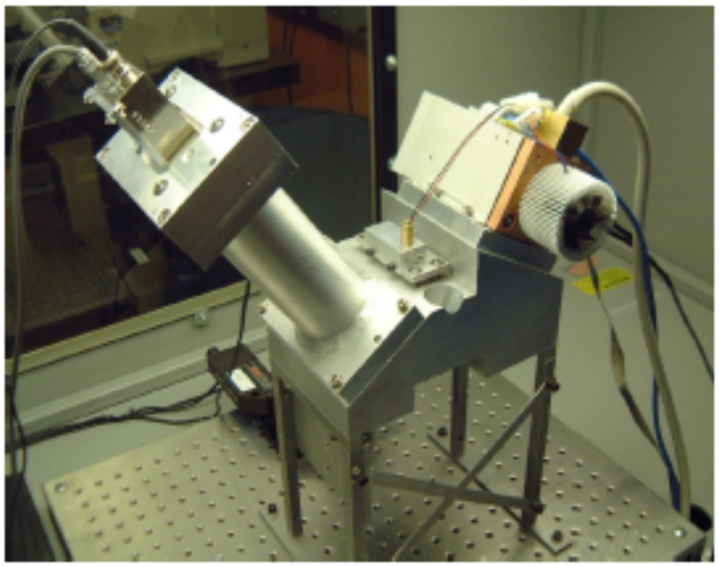
Al ripple target



3D mapping of ripple and step targets to ~ 250 nm accuracy

3D Imaging and Quantification

Confocal Micro X-ray Fluorescence
-3D elemental Imaging
-3D density measurements
-30 micron resolution

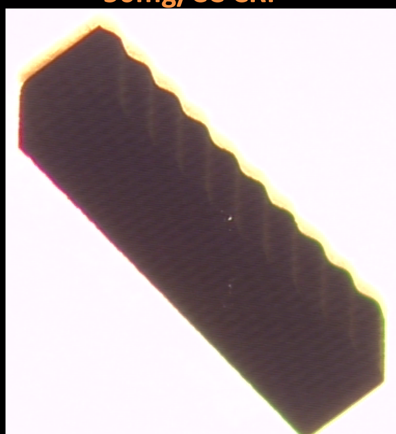


Micro X-ray Computed Tomography
- non-destructive 3D imaging
- 2 micron resolution

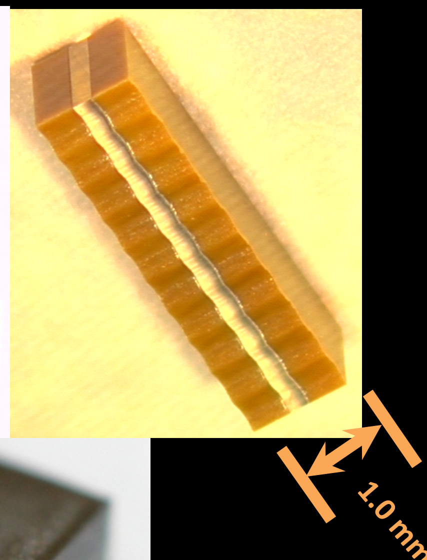
Other imaging techniques available include: scanning electron microscopes, surface scanning laser confocal microscopy.

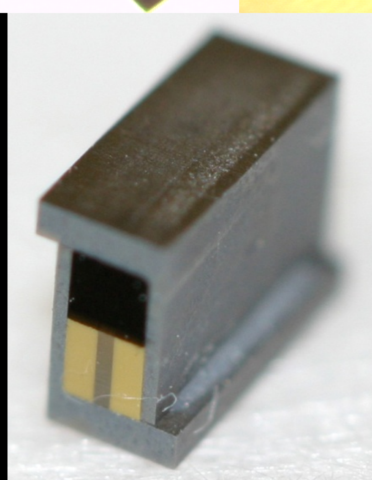
Shear instability (Kelvin-Helmholtz) targets fielded at Omega with University of Michigan required ripples machined in low density foam

50mg/CC CRF



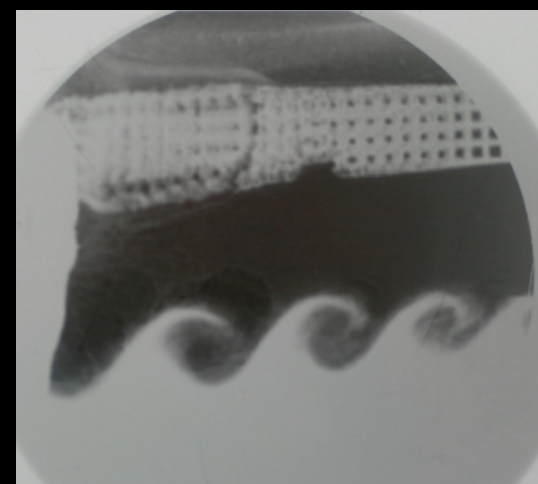
Plastic w/tracer





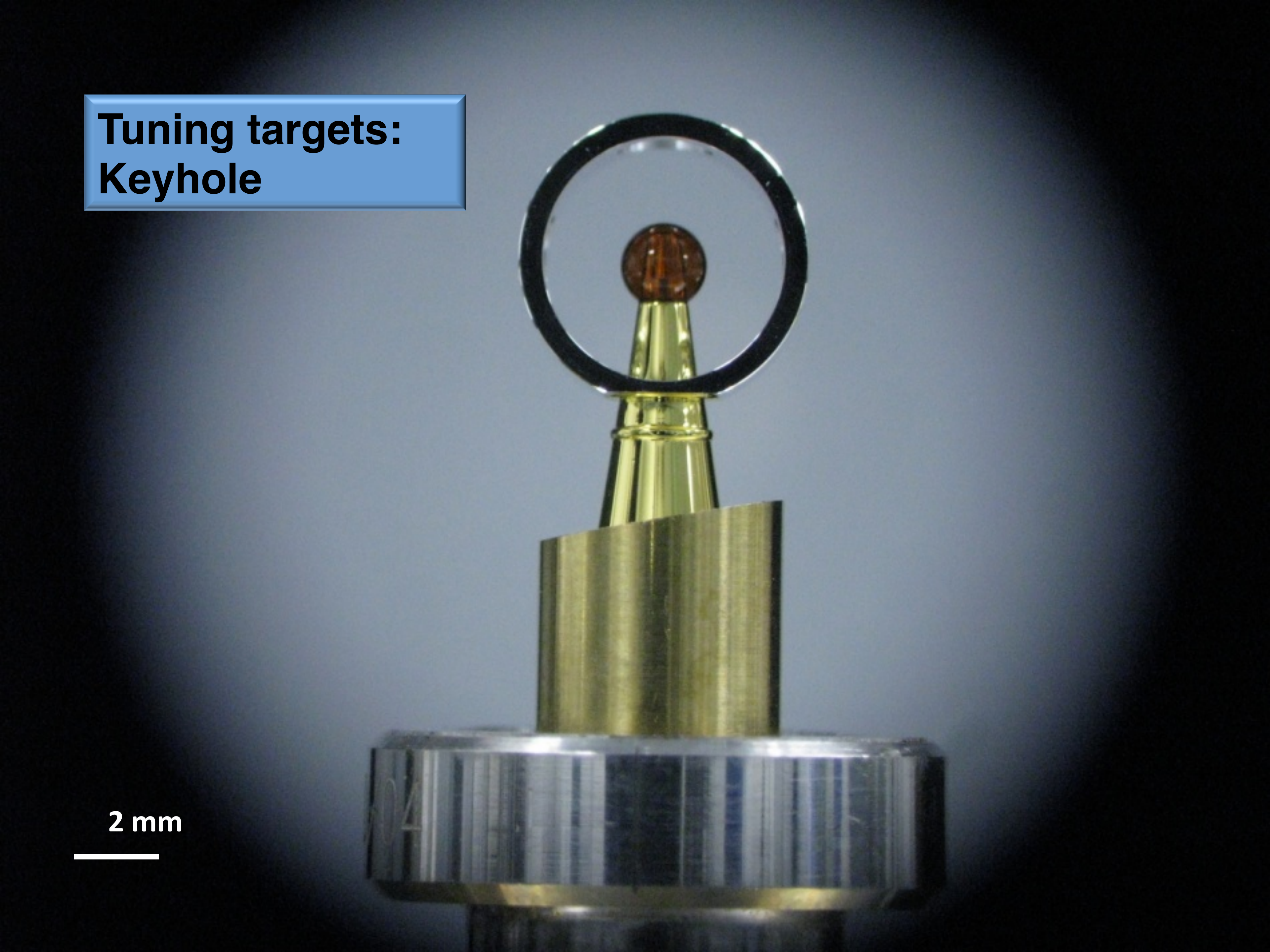
Assembled Physics Package

Materials are chosen to match the physical scaling

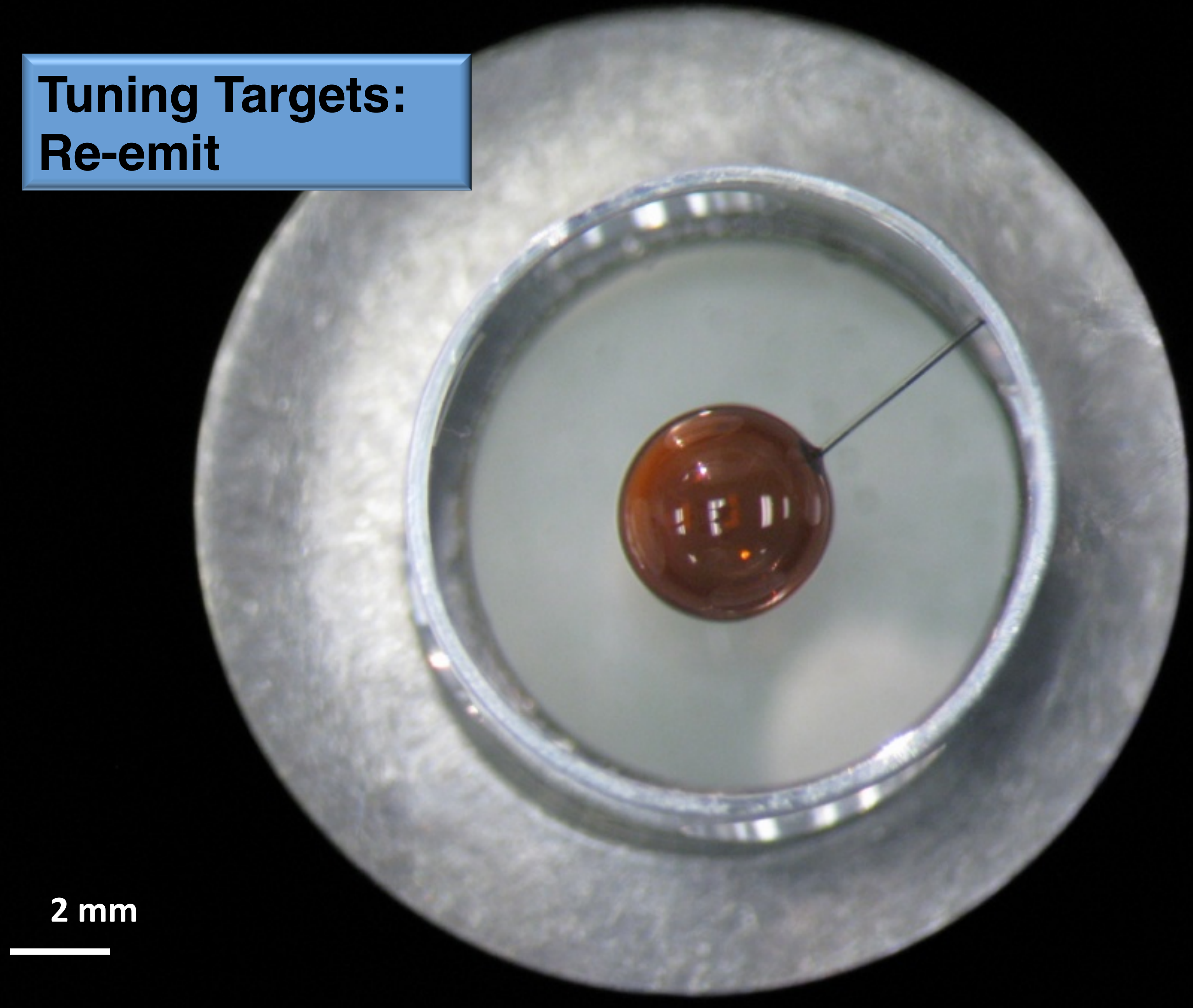


Backlit Image of Instability

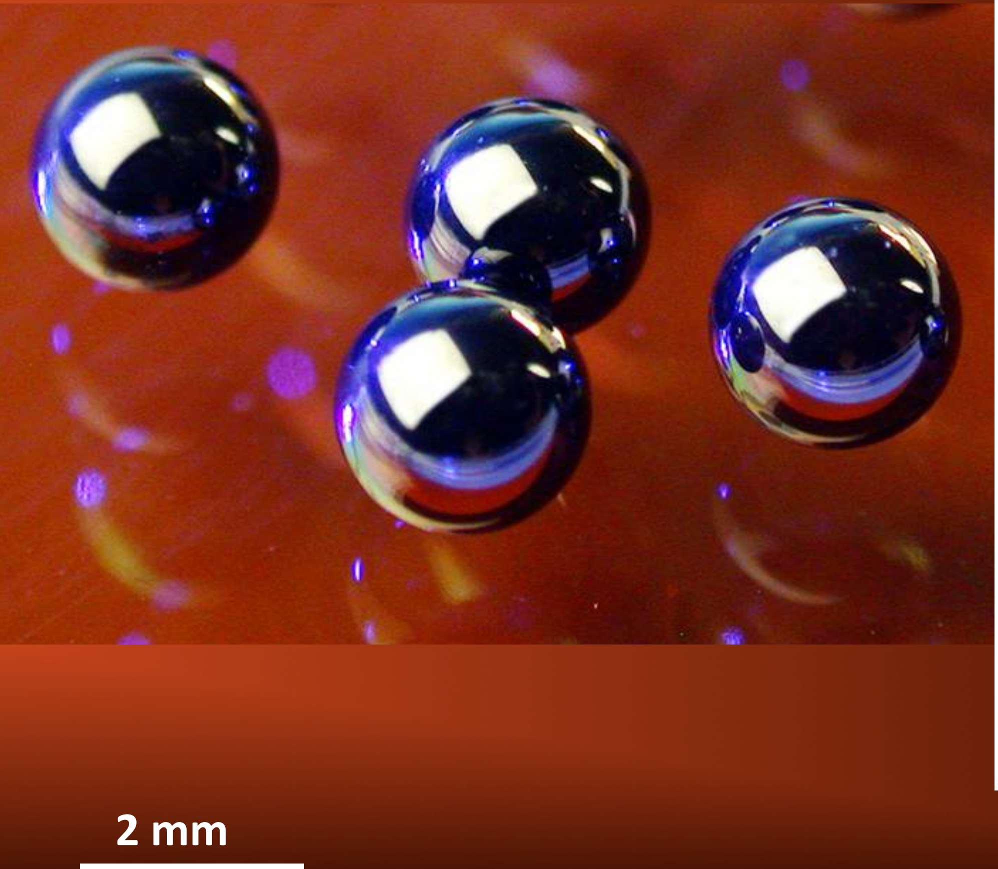
Tuning targets: Keyhole

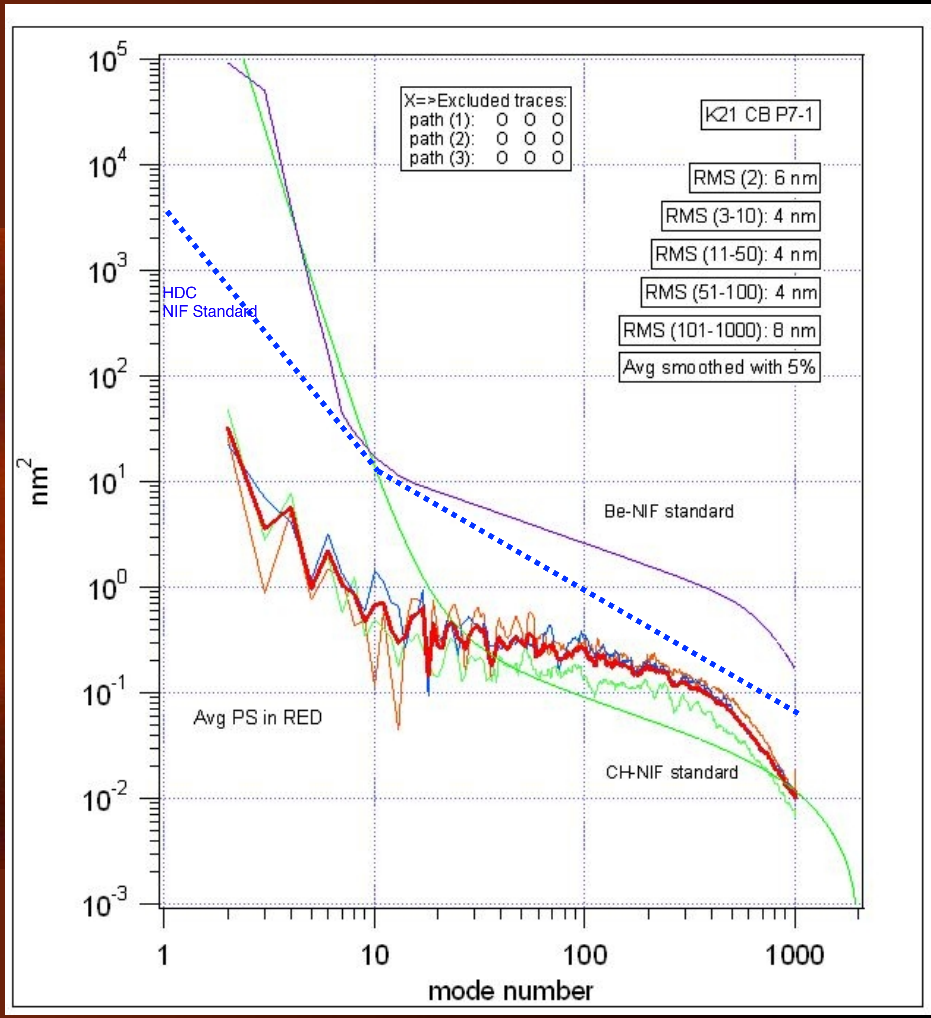


Tuning Targets:
Re-emit

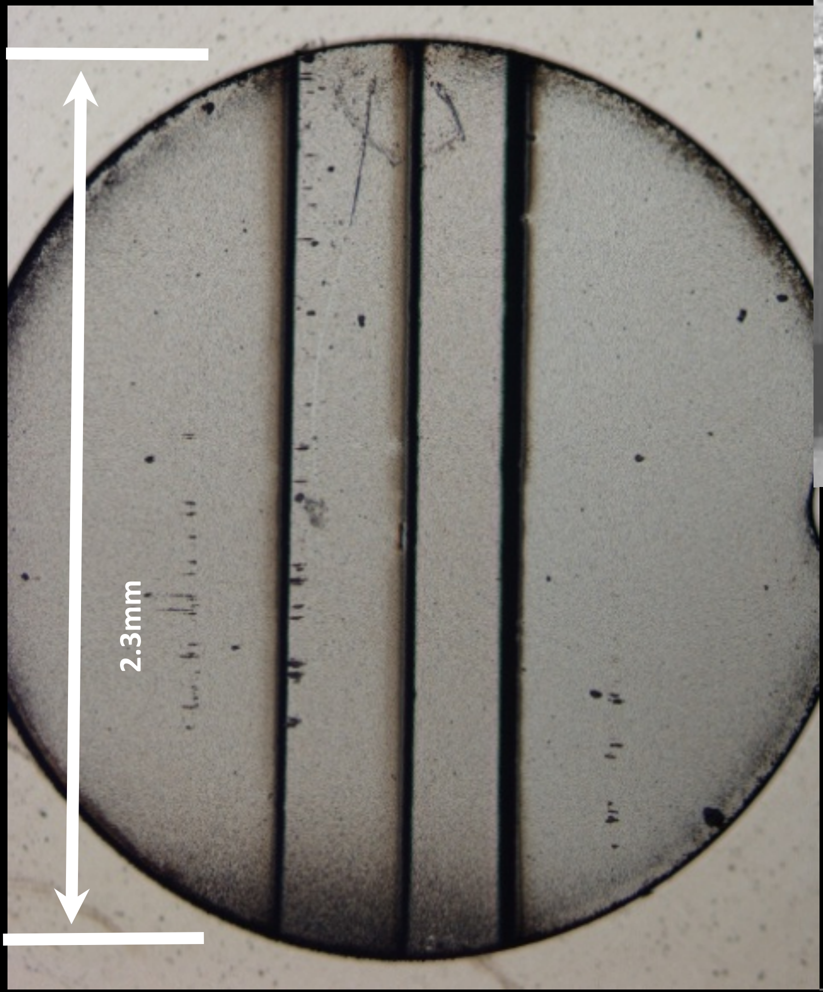


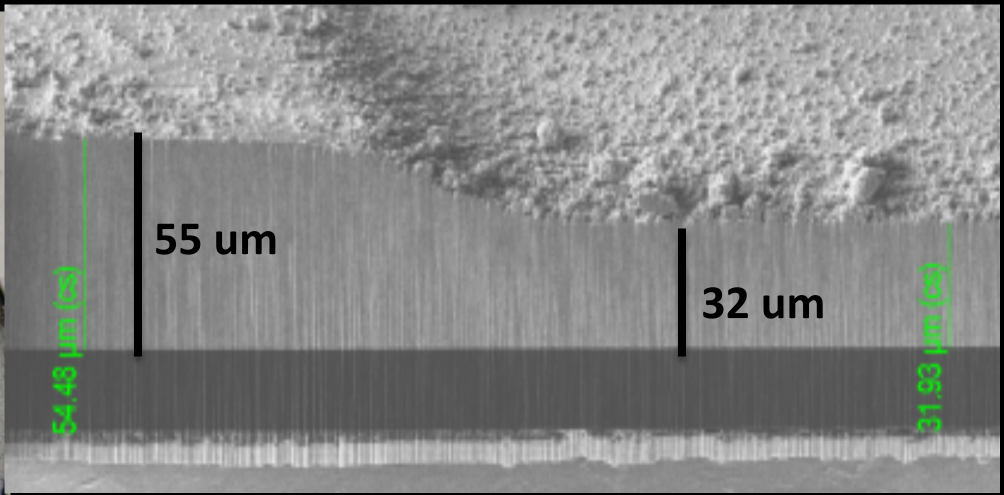
High Density Carbon ICF Capsules

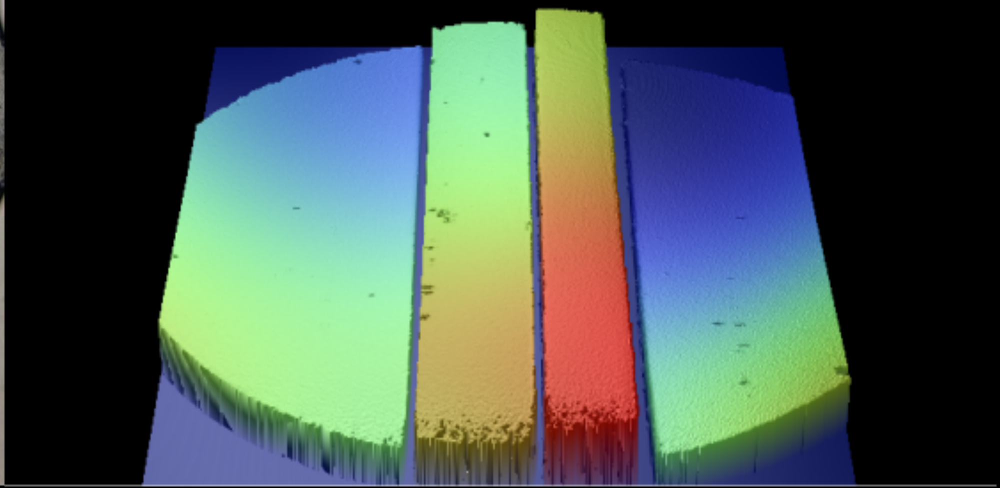




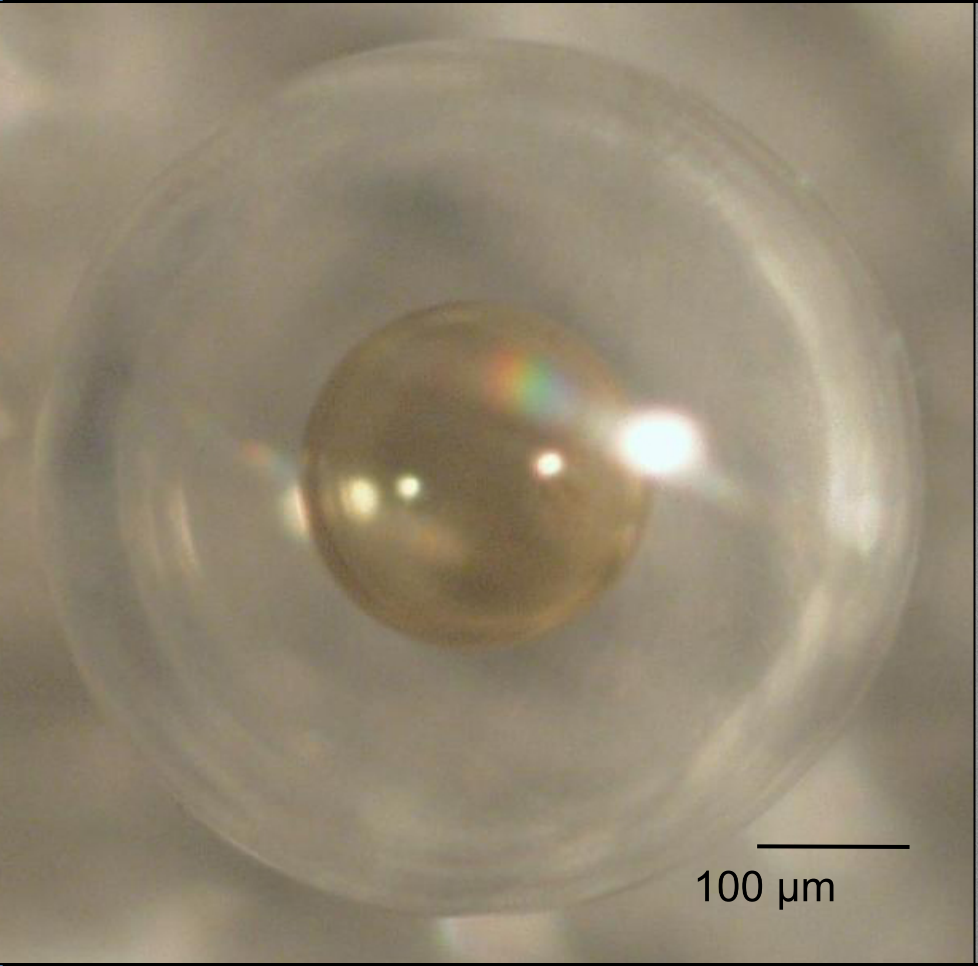
EOS Step Target Sample

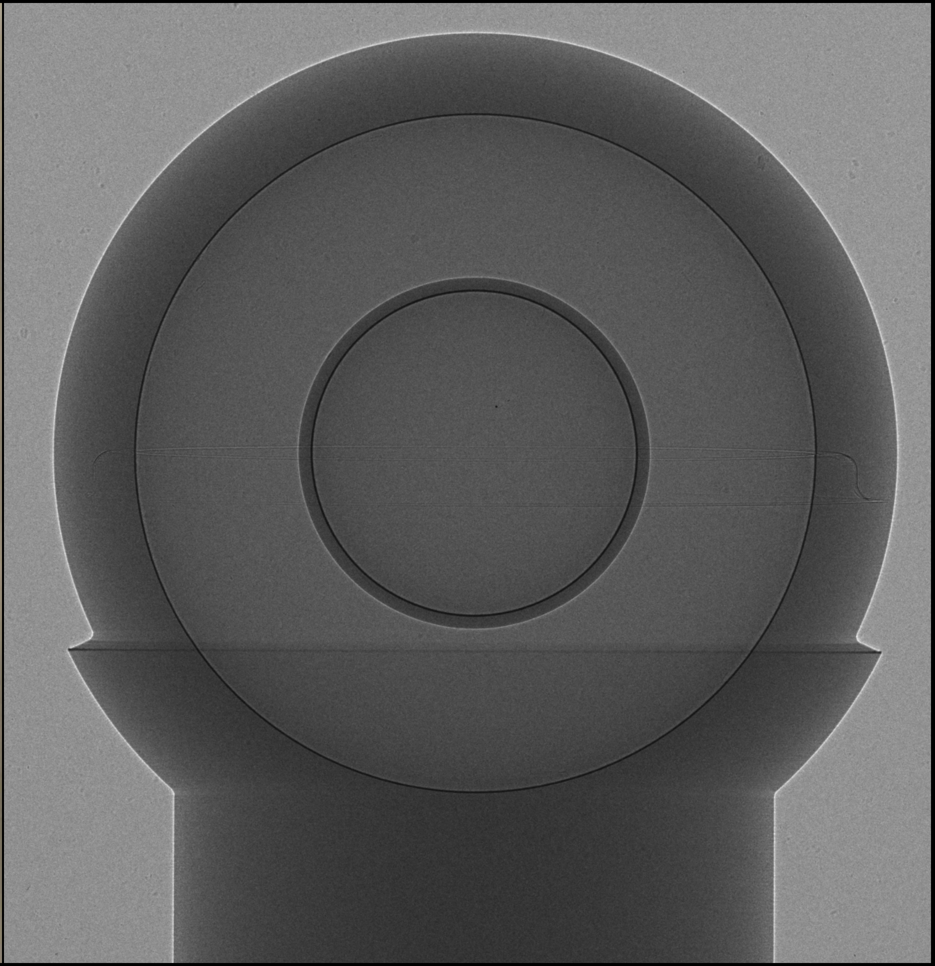




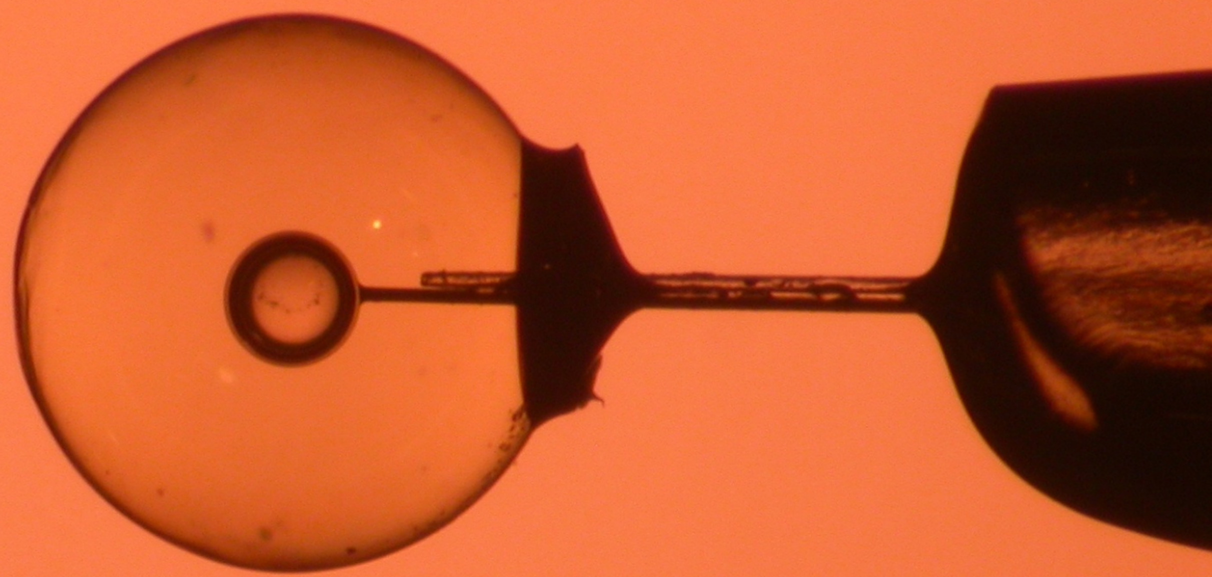


Double shells require precision and novel engineering





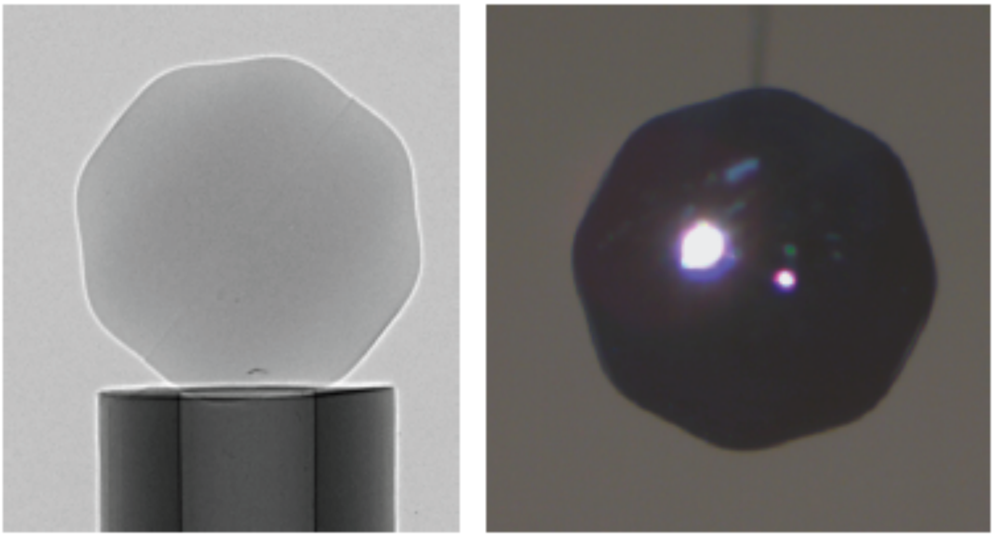
Dymanic Hohlraum Target



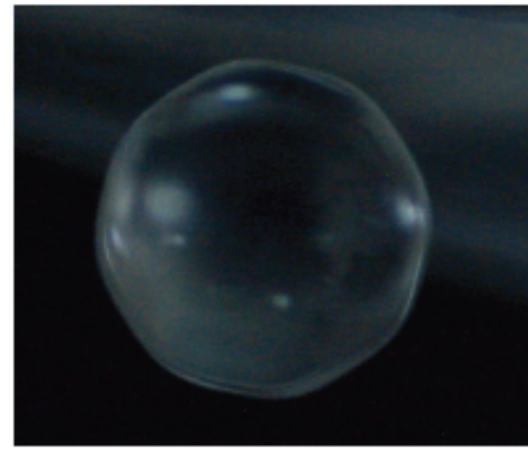
1.2 mm

GENERAL ATOMICS

Machined capsules with P8 Modulations at different amplitudes



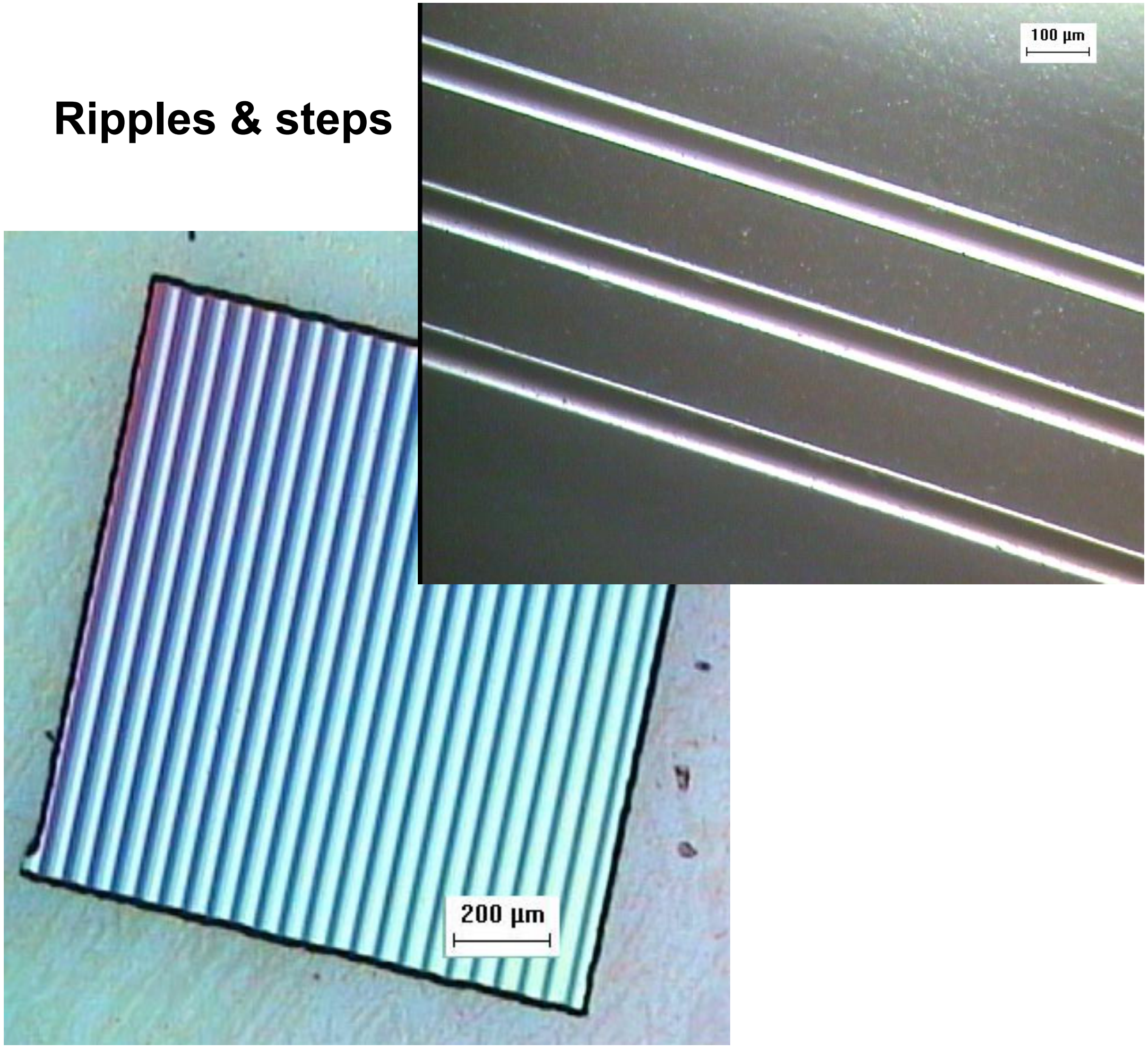
CT scan and image of 10um sinewave capsules for April 2011 ABEX

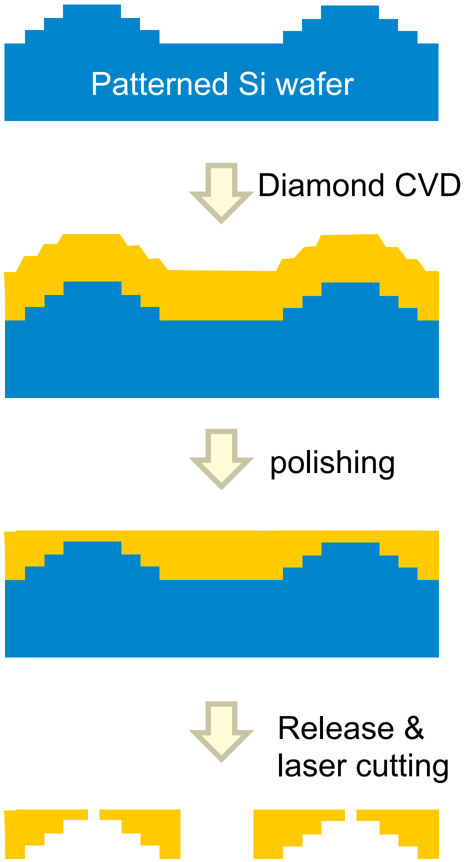


5 um amplitude pertubations

Capability to fabricate complex diamond targets for HED physics experiments

Ripples & steps

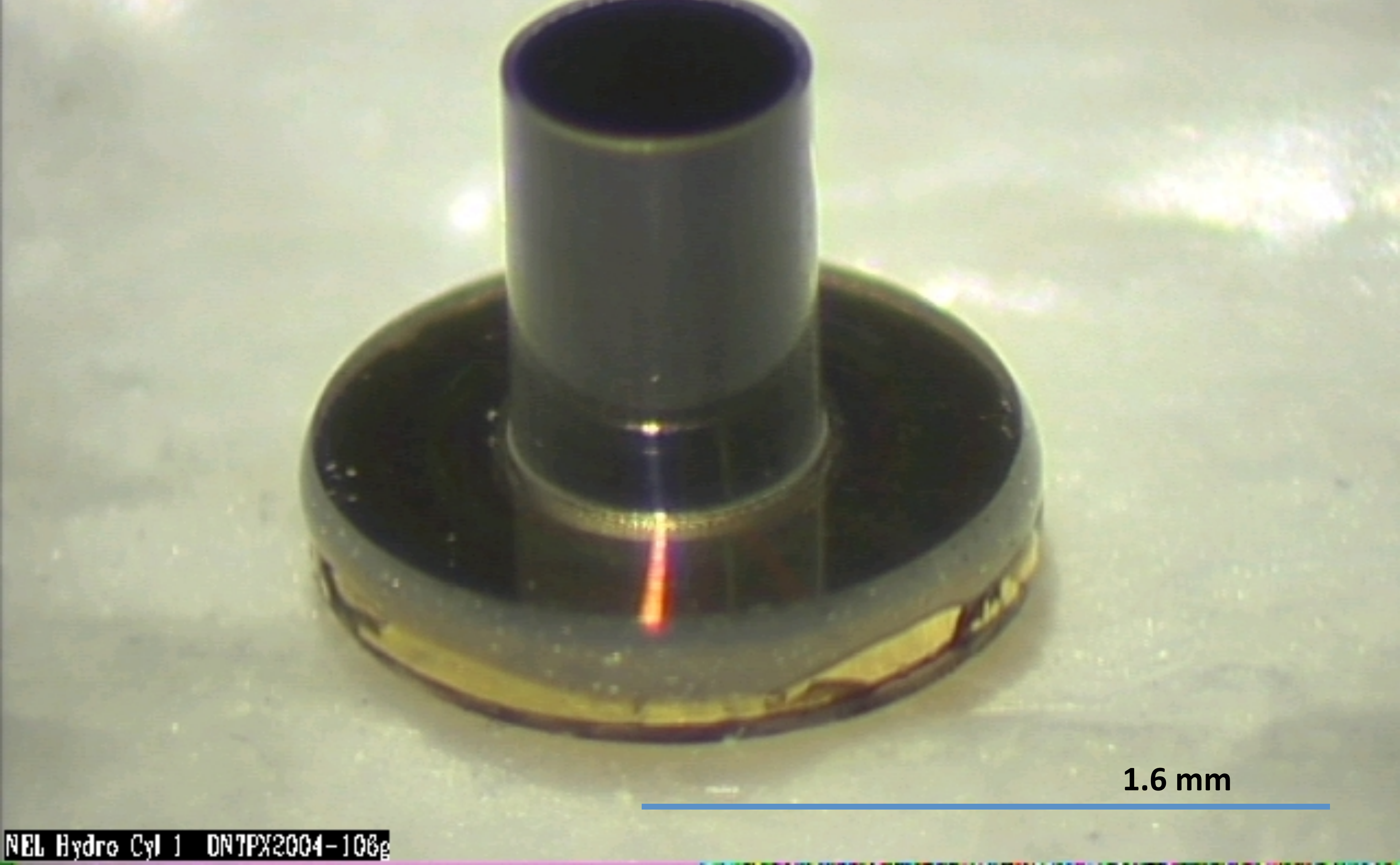


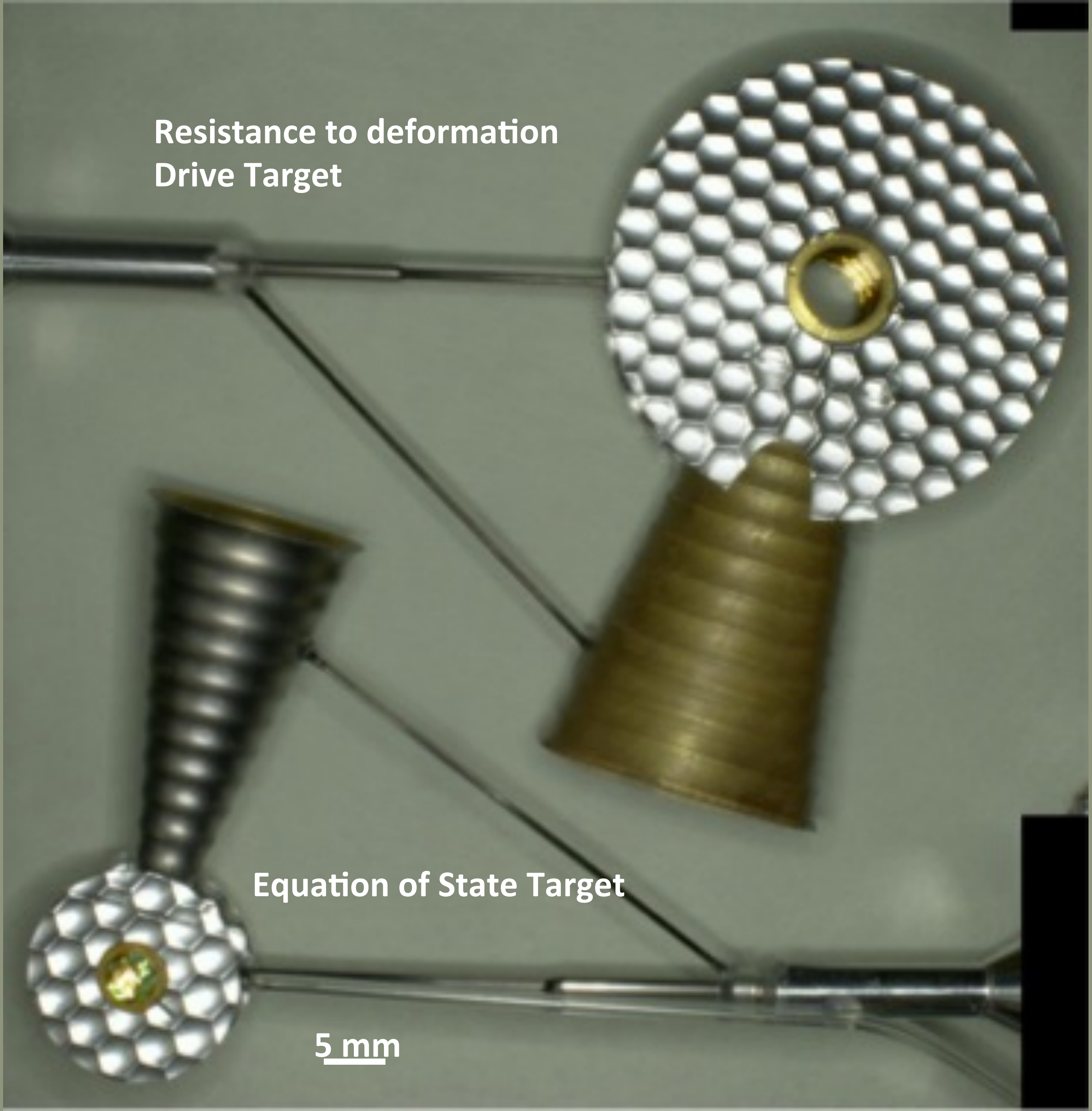



NIF

Energy Balance

NEL Hydro Experiment

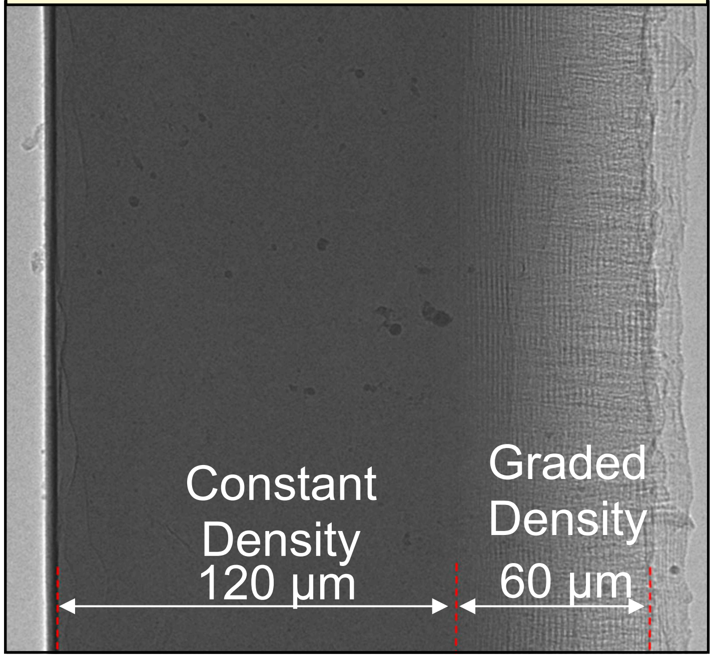




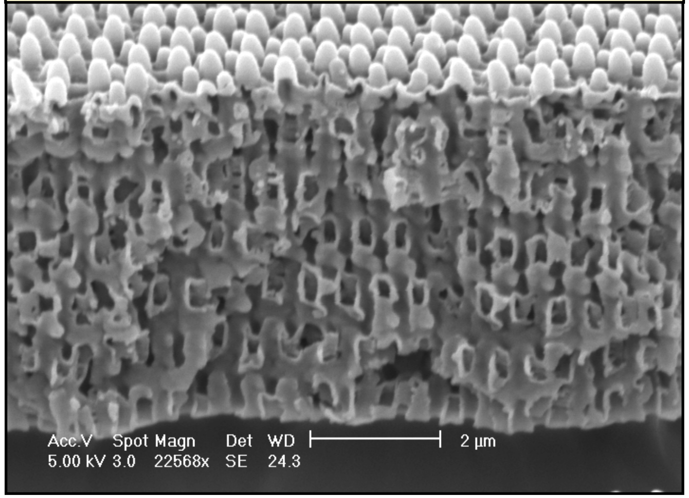
Resistance to deformation
Drive Target
Equation of State Target
5 mm

Materials Dynamics

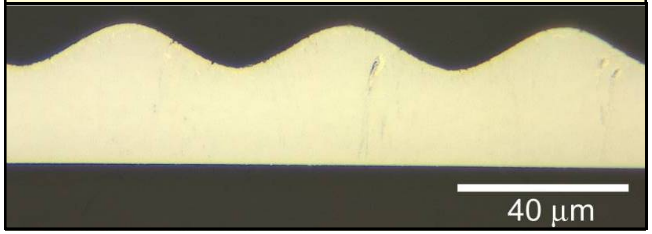
Graded Density Reservoir (GDR) to Prevent Shock Melting



Advanced Nanolithography to Produce Complex 3D Structures



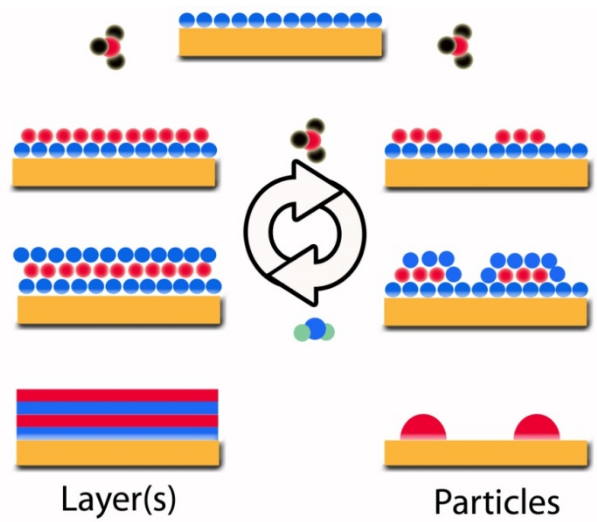
Tantalum Target Sample



Atomic-layer-deposition (ALD) is ideally suited to coat ultra-high aspect ratio materials with uniform and conformal films

ALD employs sequential, self-limiting surface reactions to overcome diffusion limitations. Both conformal films (left) and individual nanoparticles (right) can be grown, depending on the surface chemistry

The $Al(CH_3)_3/H_2O$ process: Growth rate ~ 0.1 nm @ 35-300 ^0C



Overall stoichiometry

$$Al(CH_3)_3(g) + {}^3/_2H_2O(g) \rightarrow {}^1/_2Al_2O_3(s) + 3CH_4(g)$$

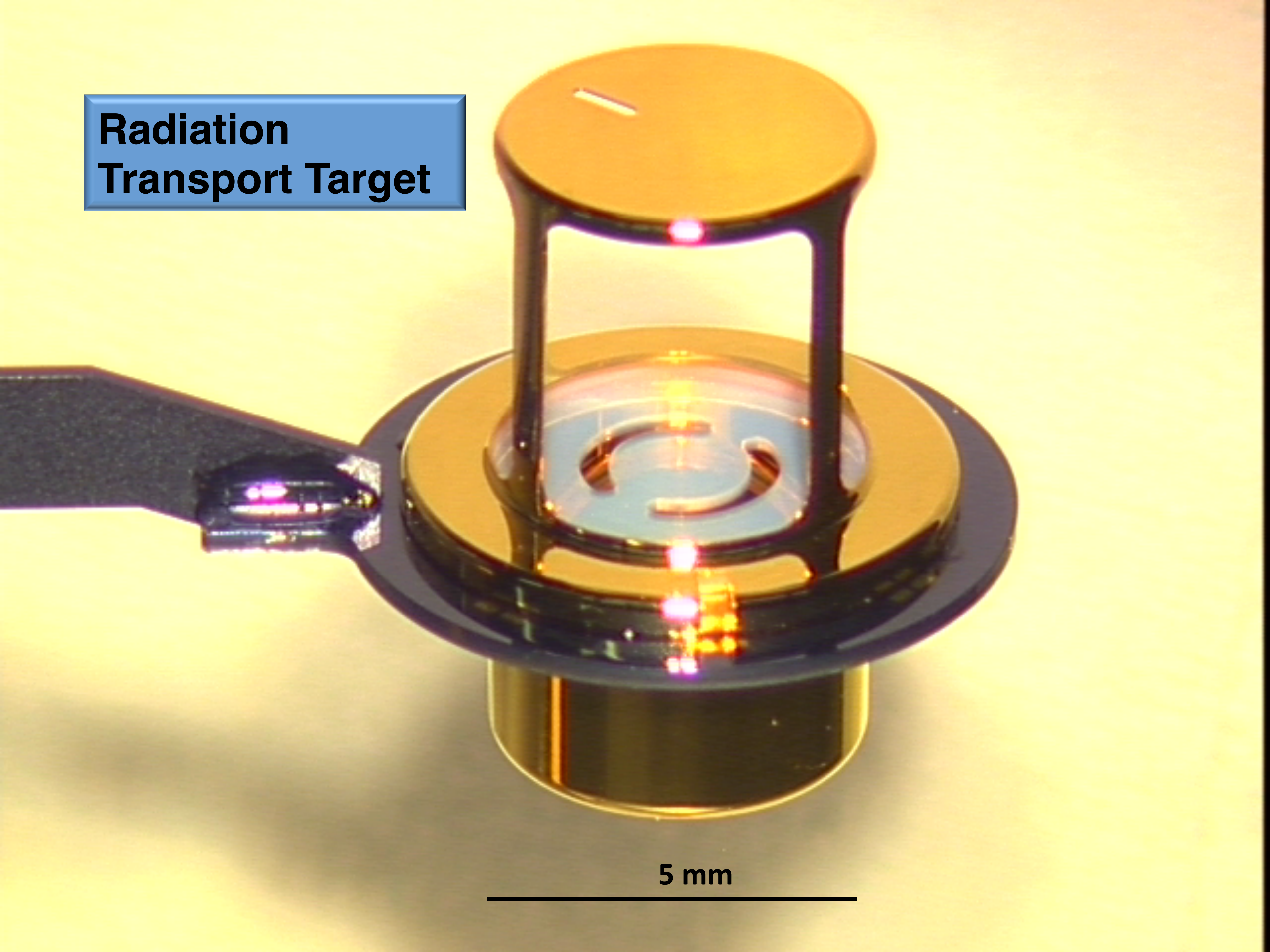
Half reactions

a) $2\|{-OH} + Al(CH_3)_3(g) \rightarrow (\|O-)_2AlCH_3 + 2CH_4(g)$

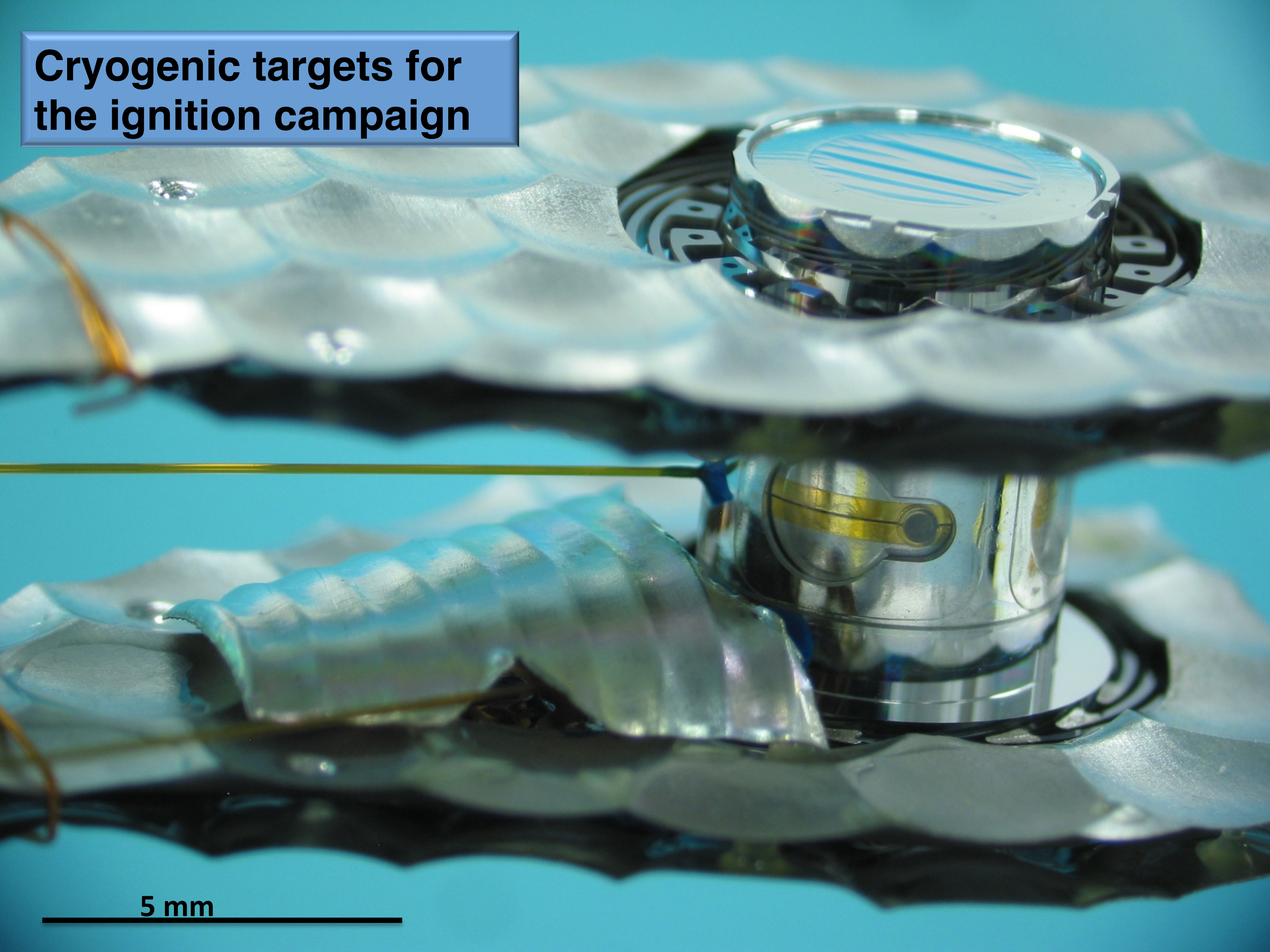
b) $\|{-CH_3} + H_2O(g) \rightarrow \|{-OH} + CH_4(g)$

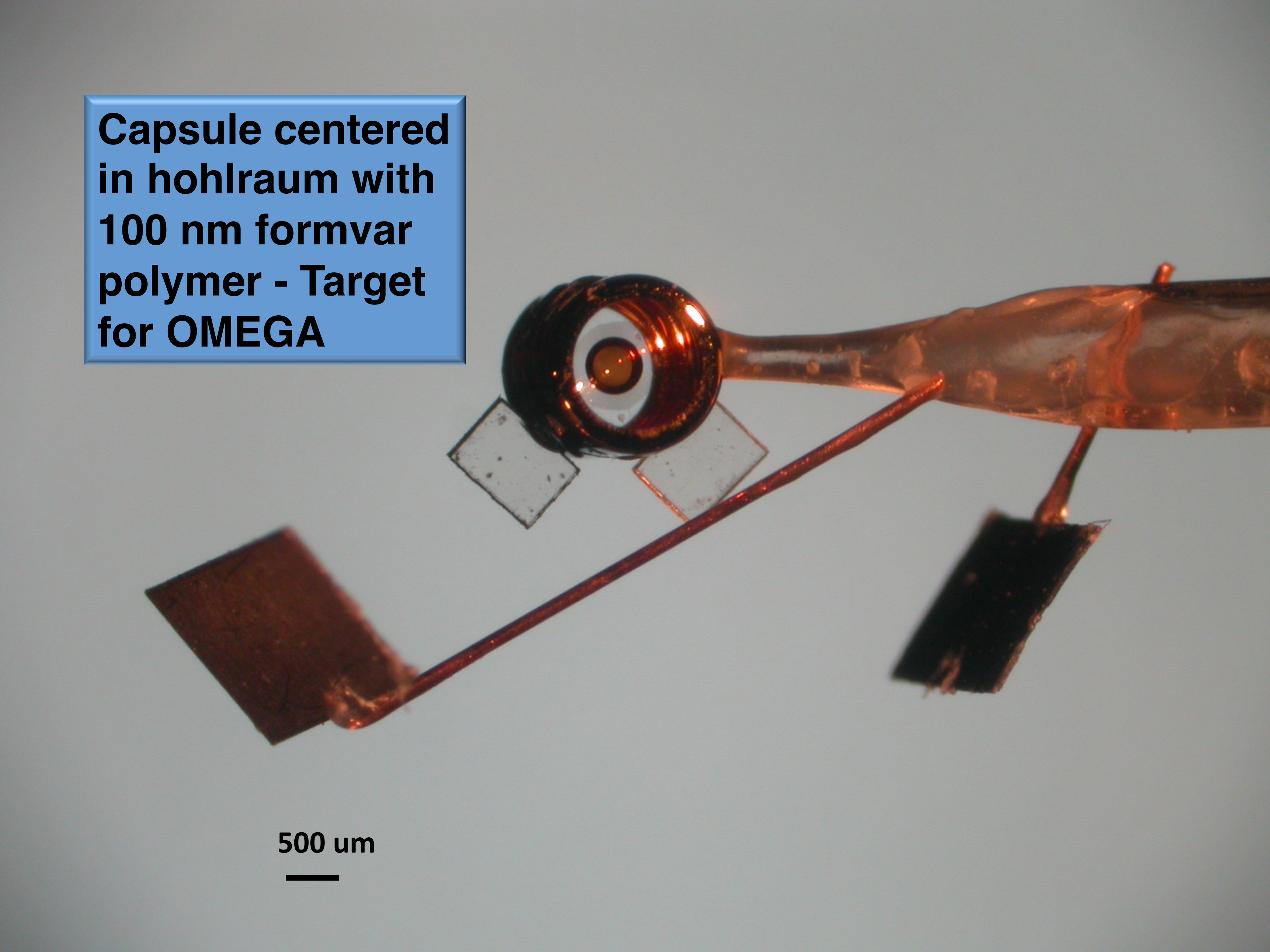
Other possible ALD processes:

TiO_2 ($TiCl_4/H_2O$), ZnO ($Zn(C_2H_5)_2/H_2O$), W (WF_6/B_2H_6).

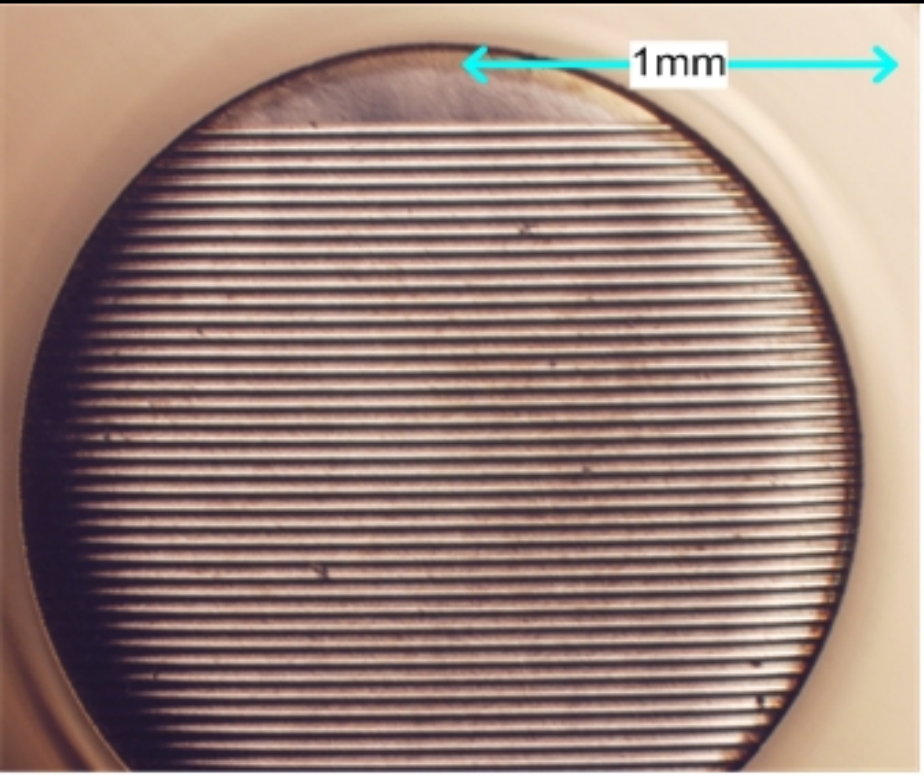

Radiation
Transport Target
5 mm

Cryogenic targets for the ignition campaign

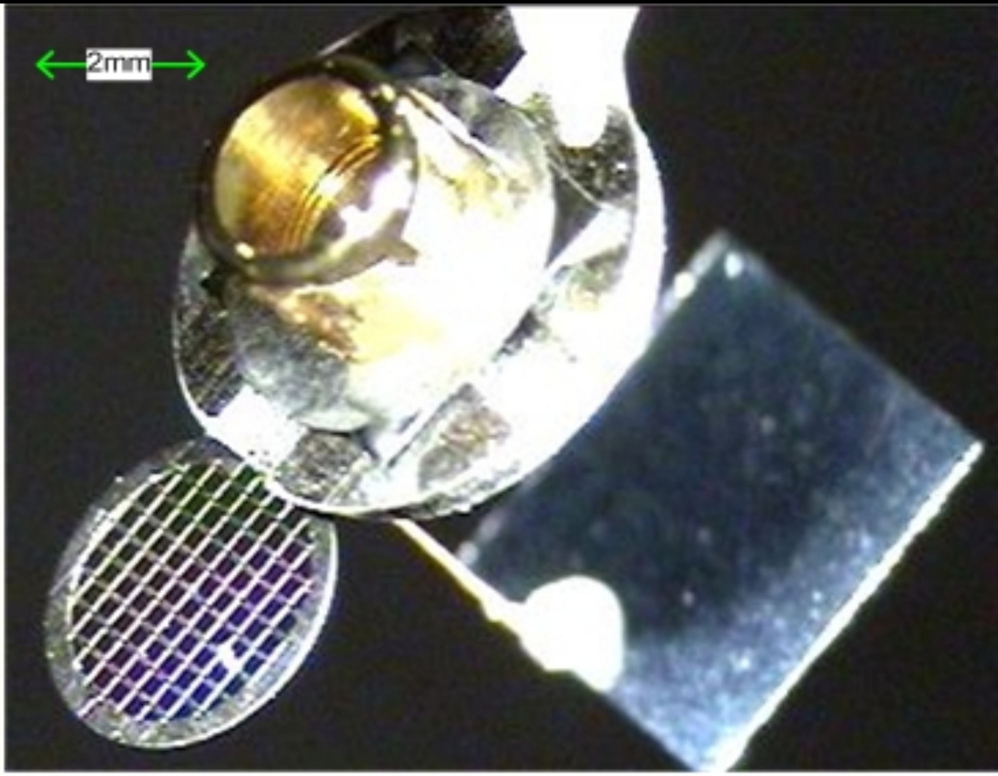



Capsule centered in hohlraum with 100 nm formvar polymer - Target for OMEGA
500 um

Materials Dynamics



Vanadium Ripple Sample



Vanadium Ripple Omega Target